Prepared for:
U.S. Army Corps of Engineers
Portland District



Surface Bypass Program Comprehensive Review Report

Contract No. W9127N-06-D-0004, T.O. 01

ENSR Corporation
December 31, 2007
Document No.: 09000-399-0409

ENSR | AECOM

Prepared for:
U.S. Army Corps of Engineers
Portland District

Surface Bypass Program Comprehensive Review Report

Contract No. W9127N-06-D-0004, T.O. 01

Prepared By

Charles E. "Chick" Sweeney, P.E. and Rebecca Hall, ENSR Corporation

Albert E. Giorgi, Ph.D and Mark Miller, BioAnalysts, Inc.

Gary E. Johnson, Pacific Northwest National Laboratory

ENSR Corporation
December 31, 2007
Document No.: 09000-399-0409

Executive Summary

Purpose

Over the past 25 years, surface flow bypasses or outlets (SFOs) have been developed to provide safe passage routes for downstream migrant juvenile salmonids at dams throughout the Pacific Northwest. User groups include the U.S. Army Corps of Engineers Portland and Walla Walla Districts, mid-Columbia Public Utility districts (PUDs), and regional private utilities. The development work, performed by Corps, PUD, and private utility staff, fisheries managers, and consultants, has been reported in a multitude of different documents. As the Corps moves forward with further SFO development there is an understandable desire to take advantage of the knowledge gained and lessons learned in previous SFO development efforts.

The purpose of this compendium is to compile and synthesize the knowledge base regarding SFO design and evaluation by producing a single reference documenting SFO development in the Pacific Northwest. Furthermore, this compendium provides lessons learned from success and failures and general design and operational considerations for biologists and engineers to use in future SFO projects.

Process

Development of this report was the result of a comprehensive research process. First, our team, in cooperation with the Corps' technical leads from both Portland and Walla Walla Districts, defined the group of projects to be included in the review. The projects cover developments on the mainstem Columbia and Snake rivers and other Pacific Northwest rivers. The projects included in our review, organized by river system and identified by owner are:

<u>Mid-Columbia River, Washington</u>

- Wells Hydroelectric Project – Public Utility District No. 1 of Douglas County
- Rocky Reach Hydroelectric Project – Public Utility District No. 1 of Chelan County
- Rock Island Hydroelectric Project – Public Utility District No. 1 of Chelan County
- Priest Rapids Hydroelectric Project (both Wanapum and Priest Rapids Developments) – Public Utility District No. 1 of Grant County

<u>Lower Snake River, Washington</u>

- Lower Granite Dam – U.S. Army Corps of Engineers Walla Walla District
- Little Goose Dam – U.S. Army Corps of Engineers Walla Walla District
- Lower Monumental Dam – U.S. Army Corps of Engineers Walla Walla District
- Ice Harbor Dam – U.S. Army Corps of Engineers Walla Walla District

<u>Lower Columbia River, Washington and Oregon</u>

- McNary Dam – U.S. Army Corps of Engineers Walla Walla District

- John Day Dam – U. S. Army Corps of Engineers Portland District
- The Dalles Dam – U.S. Army Corps of Engineers Portland District
- Bonneville Dam (First and Second Powerhouse) – U. S. Army Corps of Engineers Portland District

Cowlitz River, Washington

- Mayfield Dam – Tacoma Power Utilities
- Cowlitz Falls Dam – Public Utility District No. 1 of Lewis County

Other Rivers

- Baker River, Washington – Baker River Hydroelectric Project (Upper and Lower Baker Dams) – Puget Sound Energy
- Deschutes River, Oregon – Round Butte Dam – Portland General Electric
- Willamette River, Oregon – T.W. Sullivan Hydroelectric Project – Portland General Electric
- Clackamas River, Oregon – North Fork Hydroelectric Project – Portland General Electric
- Green River, Washington – Howard Hansen Dam – U.S. Army Corps of Engineers Seattle District and Tacoma Water Utilities

We developed a bibliography of over 500 references on biological, engineering, and multidisciplinary studies of SFO development at these facilities, plus general references on SFO development and performance. We reviewed and annotated the relevant references to provide a basis for preparing detailed descriptions of SFO design and biological performance of the projects. The bibliography and annotations are included in Appendix D.

In parallel with annotating references we prepared a conceptual framework of how SFOs work, which is presented in Chapter 2 of this report. The conceptual framework breaks SFOs into defined structural elements including entrance, conveyance, and outfall structures. SFO entrance characteristics can be categorized in terms of physics-based entrance flow regimes, either critical or subcritical flow. Combinations of structural elements may be used to adapt the SFO to a particular set of site and structure requirements, resulting in four main types of SFOs in use in the Pacific Northwest: forebay collectors, powerhouse retrofits, sluiceways, and surface spills. Fish encounter and passage at a project are described in terms of five major spatial zones: Approach, Discovery, Decision, Conveyance, and Outfall. Premises for SFO performance provide a basis to understand success and failure of SFOs.

Following the literature review, we convened a workshop with invited presentations from representatives of the owner organizations on the selected SFO projects. Notes from this workshop are included in Appendix A to the report. Following the workshop, we captured and expanded on the presentations to prepare detailed project descriptions for each of the selected facilities. The preparation of these descriptions was a product, in many cases, of collaboration between our team and the presenters as we requested their input and additional information that had not been included in their original presentations. The detailed descriptions include biological performance data, engineering designs, drawings, photos, bathymetry data, and flow field information from hydraulic modeling, where available. These detailed descriptions are included in Appendix C. We also consolidated information on the pertinent physical characteristics of the projects and a common set of biological performance parameters in a set of matrices that are included in Appendix B.

We synopsized the information presented in the detailed project descriptions and information matrices in the appendices to provide a common currency for comparing the projects. We then analyzed and synthesized the information to determine linkages between SFO performance and biological, engineering, and development parameters. From theses results, we identified design considerations, information deficiencies, and a development process model. Not only was the information used derived from presently active SFOs in the region, but we also considered the lessons learned through prototype tests leading to these facilities, and, in some cases, facilities that were abandoned due to inadequate performance or cost constraints.

Results

Through the process described above, we identified important factors to consider in SFO design. We determined that there are no silver bullets that will guarantee a successful SFO, but rather that consideration of a number of SFO design elements is necessary to achieve success. These elements include factors in the Discovery Zone that affect vertical distribution of fish in the project forebay relative to the SFO entrance(s) and horizontal concentration of fish relative to the SFO entrance(s), plus the Decision Zone elements that define the SFO entrance conditions themselves. Conveyance and outfall components of the SFO system are important for high survival rates.

A number of overarching themes were distilled from the collective information:

- SFO type is not a primary factor affecting fish collection efficiency. Indeed all four SFO types (retrofit, sluice, surface spill, and forebay collector) are represented in the top performers. Of more importance may be characteristics concerning SFO location, fish concentration, and entrance conditions.

- In general, the best performing SFOs tend to have more of the features that we suggest contribute to high collection efficiency. This suggests that design teams should consider at least the breadth of features when formulating SFO designs and placement of entrances. Furthermore, we generally observed that good entrance conditions cannot override the need for features that contribute to vertical and horizontal concentration of smolts or locating entrances in locales where smolts naturally congregate. This is evidenced by the observation that the lowest performing SFOs lacked features that concentrate fish vertically and horizontally.

- By inference through observations regarding competing flow nets and eddy-lateral current flows, in general smolts follow the bulk flow patterns as they approach a project.

- Location of the SFO entrance(s) relative to smolt pathways and concentration areas in the forebay is a primary consideration for maximizing fish collection efficiency (FCE). Both vertical and horizontal distribution of smolts is important in this regard. Natural features like sills and shallowing forebays are beneficial in that they shift the population up toward the SFO. In turn, extending the depth of the invert can increase the probability of encounter. In the horizontal plane, natural features like cul-de-sacs, lateral currents, or eddies can direct smolts toward an SFO. Absent these features, physical guidance devices can serve to direct fish horizontally toward an SFO or multiple entrances can increase the probability of fish discovery of an entrance.

- A particular dam configuration does not create conditions that guarantee success. For example, the Wells Dam (hydrocombine) SFO performed well, whereas at the Cowlitz hydrocombine the SFO facility did not. Both projects are configured as hydrocombines and have features that foster horizontal and vertical concentration. However, poor conditions of velocity gradient downstream from the entrance and before capture at Cowlitz may have negated those benefits. In addition there is a difference of configuration downstream from the entrances and a difference in scale between Wells and Cowlitz.

- Competing broad scale flow nets from different passage routes influence SFO performance to varying degrees.

- SFO fish collection efficiency of subyearling Chinook salmon during the summer rivaled that of yearling Chinook in the spring. Fewer studies have examined summer migrants, but generally at sites where these studies have been implemented, performance for spring and summer fish was similar.

- Species matter. The optimum SFO design is species dependent. There is some evidence that certain SFO types may be less effective for certain species.

- Safe conveyance and outfall conditions must be attended to.

A number of design considerations were derived from our review of the material presented in the report and are, organized by zone.

Approach and Discovery: Fish follow the bulk flow patterns as they approach a project. At sites where the bulk flow splits in different directions, the smolt population splits too, in some cases diminishing encounter with the SFO entrance location. This leads to several guidelines relative to project layout and SFO placement:

- Put the entrance where the fish are at. SFO placement at linear dams is best in a location where the bulk flow to the dam delivers fish to proximity of the SFO.

- SFO placement at Z-dams, with the powerhouse axis parallel to the river, is best within the cul-de-sac near the downstream end of the powerhouse, where the downstream most migration point is reached, an eddy is formed, and the entrance should be located along the periphery of the eddy.

- At projects where there are no layout or flow field features available to concentrate fish, something must be done to horizontally concentrate fish or provide multiple entrances. Either a significant SFO flow or a forebay guidance device may be required to aid discovery of the SFO flow net. Alternatively, placing the SFO in known migratory pathways may maximize probability of SFO discovery and affording smolts access to a surface outlet.

- Careful consideration of turbine priorities and spillway operations during SFO design, evaluation, and long-term implementation is important because operating priorities can affect bulk flow patterns, which in turn affect fish passage patterns.

Decision: Juvenile salmonids will readily pass into a surface flow outlet if the entrance conditions are “right.” Although exact physical and hydraulic specifications for what is “right” are not precisely known, we offer these points for consideration:

- Entrance efficiency is enhanced by achieving near capture velocity at the entrance plane of the SFO. Based on our review, we hypothesize that maximizing the entrance area and the velocity at the flow control location downstream from the SFO entrance plane enhances passage at these SFOs.

- Flow deceleration should be avoided at any location upstream from capture.

- Rapid acceleration within a confined SFO structure, but before capture, should be avoided. It is better to achieve capture near the SFO entrance. However, there probably is a threshold acceleration that should not be exceeded even in the unconfined approach to an SFO entrance.

- SFO designs must be holistic. For example, the hydraulic design characteristics of the Wells Dam retrofit SFO are not always applicable to other projects. The region focused on entrance conditions.

However, developers did not consider the interaction of all components. The Wells SFO is a success because vertical, horizontal, and entrance conditions are optimal.

Conveyance and Outfall: The primary purpose of the conveyance and outfall structures is safe passage from the forebay to the tailrace. To this end, we make the following suggestions:

- High flow dewatering for fish is possible and should be considered if necessary.
- High flow outfall guidelines (PNNL et al. 2001) are applicable for design of conveyance and outfall structures.

Our review revealed several important deficiencies in the knowledge base for regional SFOs. Research addressing these topics would be useful to future SFO development efforts.

- Estimates of discovery efficiency and entrance efficiency using standard methods are sparse.
- The relationship between hydraulic and other physical conditions and fish responses in the Decision Zone within about 30 ft of SFOs is uncertain.
- The need for gradual shaping, i.e., acceleration criteria, at an SFO entrance is not well established.
- SFOs may benefit other life history stages and less abundant species, but we do not have much data on these fish.
- Research on the effect of turbine intake occlusion on SFO performance has been mixed depending on the site.
- Research on the effects of near field project operations adjacent to an SFO
- Indirect, sub-lethal effects on fish from conveyance and outfall conditions are not well understood.

We have proposed an SFO development process model that involves three phases, called Preparation, Prototype, and Production. These phases are necessarily sequential. However, within each phase there is considerable feedback and adaptive management. The scope of work within a given phase will vary depending on the SFO and the site.

This document can be used to review designs at SFOs currently under development (e.g., Baker, Howard Hanson, John Day, Little Goose, McNary, North Fork, Priest Rapids, Round Butte, Wanapum, and Willamette Falls dams). It also can be used to assess the performance of existing SFOs and make improvements through operational or physical changes or both. This compendium provides a conceptual framework with standardized terminology to foster communication among stakeholders. It can help guide and focus cost-effective evaluation of SFO performance and basic research on the information deficiencies mentioned above.

Research by Goodwin et al. (2006) resulted in the Stain-Velocity-Pressure hypothesis about juvenile salmonid behavior and movement in forebays and through dams. This hypothesis should be considered and, as appropriate, integrated into the SFO compendium in the future, perhaps in a workshop forum.

Updating this compendium on a regular basis to incorporate the new information that will become available from a number of SFO projects around the region that are under development is highly recommended to maintain the compendium's value and suggestions for update workshop topics are presented.

ENSR | AECOM

Contents

A fold-out list of Acronyms and Terms is found at the end of this document.

List of Tables

List of Figures

ENSR | AECOM

List of Appendices

Acknowledgements

The authors of this report, Charles “Chick” Sweeney, P.E., Al Giorgi, Ph.D., Gary Johnson, Mark Miller, and Becca Hall, prepared the report under Contract No. W9127N-06-D-0004, Task Order No. 01. This work was jointly funded by the Portland and Walla Walla Districts, U.S. Army Corps of Engineers. The government points of contact for the Portland and Walla Walla Districts were Randall Lee and Lynn Reese, respectively. The coordination, ideas, information, and reviews provided by Messrs. Lee and Reese were extremely valuable and contributed greatly to the value of this document. We would also like to acknowledge the biologists and engineers, too numerous to name here, from the Corps of Engineers, the fisheries management agencies, and both public and private electricity utilities throughout the Pacific Northwest who made presentations at, participated in, and provided information following the September 2006 workshop that was a focal point for exchange of ideas on surface flow outlets to pass juvenile salmonids at hydropower dams in the Pacific Northwest. The conclusions and recommendations presented in this report are those of the authors and are not necessarily the conclusions and recommendations of ENSR, BioAnalysts, Pacific Northwest National Laboratory, the Corps of Engineers, the fisheries management agencies, or the utilities.

1.0 Introduction

1.1 Background

In 1995, the Portland and Walla Walla districts of the U.S. Army Corps of Engineers (the Corps), in conjunction with regional fisheries management agencies, began investigating surface flow bypasses for downstream migrant juvenile salmonids. The Corps initiated a surface flow bypass program in response to a National Marine Fisheries Service (NMFS) Biological Opinion on operation of the Federal Columbia River Power System (NMFS 1995), which mandated immediate testing of surface flow bypass at Snake and Columbia river dams. Early in its development, the surface bypass program was "…an aggressive, non-traditional approach to prototype development, which involves fast-track design, construction, and testing" (USACE 1995). As outlined in the Corps' original program document (USACE 1995), "The purpose of this program is to develop and evaluate surface bypass and collection prototype concepts that will lead, if justified by prototype test results, to permanent systems for improving survival of juvenile salmon migrating past lower Snake and Columbia River hydroelectric projects, which are operated by the Corps." The mid-Columbia Public Utility Districts (PUDs) and regional private utilities are also investigating surface bypass as a means to increase juvenile salmonid passage and survival. Surface flow bypass, hereafter called surface flow outlet (SFO), is one of the primary technologies currently being applied in the Pacific Northwest to pass juvenile salmonids at hydropower dams.

As the Corps' and other surface flow bypass programs progressed and various alternatives were investigated regionally, it became apparent that many different SFO designs were possible. Further, it became clear that the driving forces for testing SFOs at different locations were often as different as the projects themselves. Following the finding that detailed biological data and fish behavioral information were lacking to assist in the design of SFO prototypes (Giorgi and Stevenson 1995), the Corps conducted several biological investigations to help fill the void. For example, specific goals for the Bonneville project were to develop baseline biological data, identify key unknowns, and attempt to test important unknowns to aid in further prototype development. Over the past 10-25 years, SFO development work has been performed by a variety of Corps, PUD, and utility staff, fisheries managers, and consultants and reported on in a multitude of different documents. Previously, authors reviewed the successes and failures in SFO development, offered reasons for particular results, and proposed premises for successful SFOs (Giorgi et al. 1998; Dauble et al. 1999; Johnson and Dauble 2006). However, these reviews focused on particular SFO sites (e.g., Lower Granite Dam) or were broad, worldwide assessments of SFO technology. None provided a comprehensive examination of biological performance and hydraulic characteristics of SFOs in the Pacific Northwest. As the Corps moves forward with decisions on the next steps in SFO development at Columbia and Snake River dams, there is a need to consolidate available information to date, including biological and hydraulic performance and development history, to take the knowledge gained and lessons learned and apply them to future SFO development efforts.

1.2 Purpose of Report

Information on SFO development and performance at both federal and non-federal projects throughout the Pacific Northwest (Figure 1-1) is scattered in hundreds of engineering and biological reports published by various entities. Given this situation, the overall objectives of this report are to 1) develop a single reference documenting SFO development in the Pacific Northwest, and 2) provide lessons learned from successes and failures and general design and operational considerations for biologists and engineers to use in future SFO development. In this report, we, the authors, assess the successes and failures of SFO development in the Northwest and provide general guiding principles for successful SFO development. However, the intent of this report is not to provide details, suggestions, or recommendations for SFO development at specific sites. If an SFO is being considered at a particular site, then SFO concepts and relevant bioengineering design work should be developed by an appropriate project team at that time. Such SFO development teams should find this document useful.

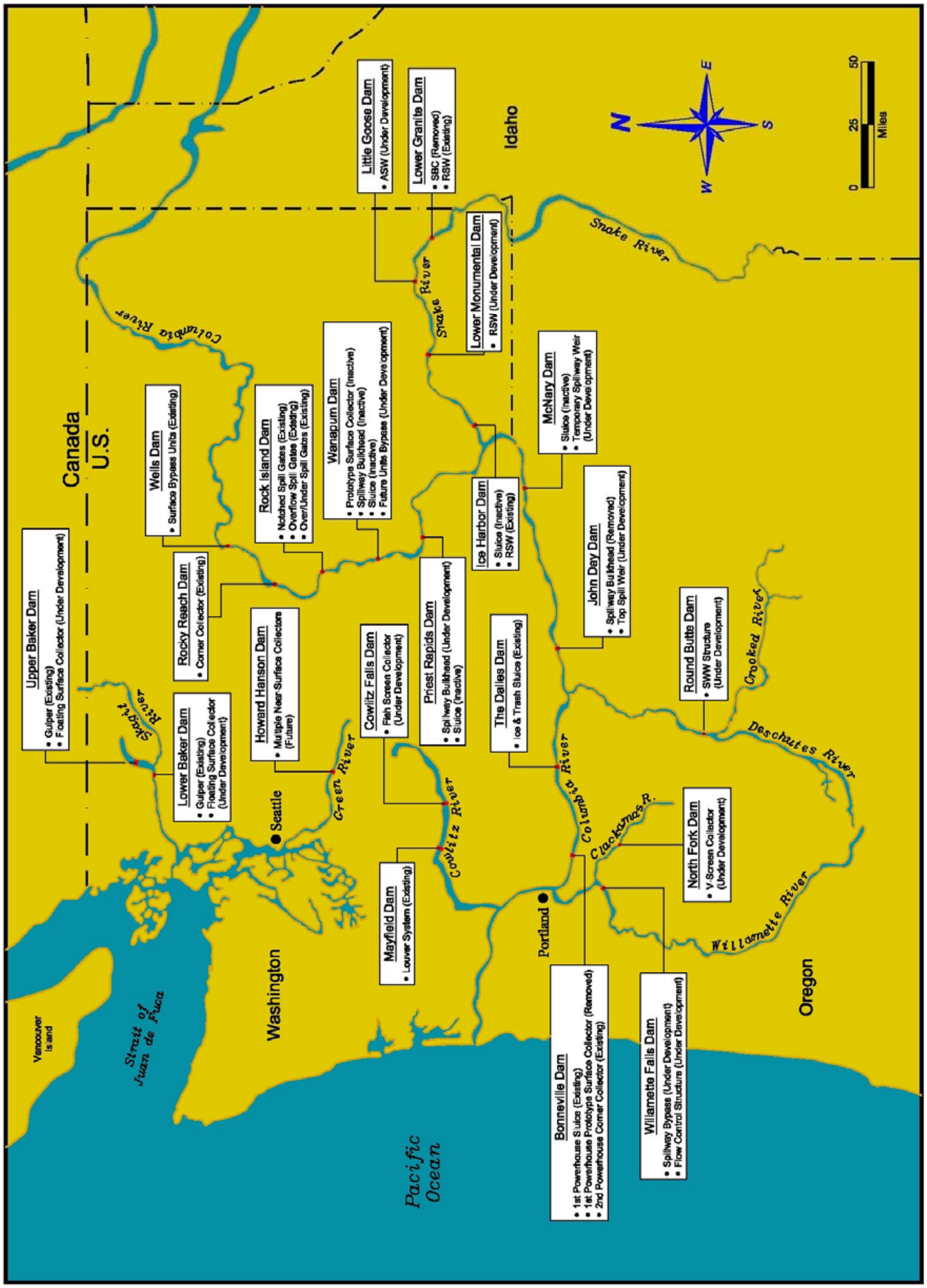


Figure 1-1. Map of hydropower dams with SFOs in the Pacific Northwest

1.3 Technical Approach

This report has been developed through a series of tasks, as follows:

- The universe of projects to be covered was established in meetings between the authors and representatives of the Corps.
- A bibliographic list of over 500 references on the subject projects was assembled, reviewed, culled, and augmented on the basis of individual knowledge of the authors and project owner/operators.
- Electronic or hard copies of the references were obtained and given a screening level review, following which the most relevant references were annotated.
- A template was developed to capture the information on SFO development at each of the subject projects.
- A conceptual framework of how an SFO works was developed based on Johnson and Dauble (2006).
- A workshop was convened with presenters invited to speak about each of the projects being addressed in the report, with the intent that the presentations would provide the basis for more detailed descriptions of these projects. Notes that captured the workshop's presentations and discussions were prepared.
- Detailed descriptions were prepared for each project following the template, based on the input from the workshop and the literature annotations.
- Synopses were developed from the detailed descriptions to bring the most pertinent information into the body of the report.
- The conceptual framework was revisited and revised as appropriate in light of the project descriptions and synopses.
- The data were synthesized and reviewed to determine associations and patterns of SFO performance to biological, engineering, and development parameters, as well as any overarching themes and lessons learned, which helped identify design considerations, information deficiencies, and a development process model.

1.4 Report Organization

Chapter 2 presents a description of SFO technology, including a conceptual framework for SFOs. Chapter 3 contains synopses of SFO development at 21 projects in the Pacific Northwest. In Chapter 4, we synthesize, analyze, and summarize the information presented in earlier chapters. Chapter 5 contains our conclusions and recommendations. Notes documenting the Workshop are in Appendix A. Matrices consolidating much of the biological, physical, and hydraulic information on SFO projects considered are in Appendix B. Detailed descriptions of these projects are presented in Appendix C; these formed the basis for the synopses in Chapter 3. The bibliography of information we used in preparation of the report is contained in Appendix D. All literature cited in the text of the report is included in the bibliography, organized by project then subject matter. Finally, a list of acronyms and terms is provided on a foldout sheet at the end of the report.

2.0 Surface Flow Outlet Technology

This section contains a description of SFO technology, including the structural components of an SFO, entrance flow regimes, types of SFOs, and a conceptual framework. This material, except for entrance flow regimes, is drawn largely from Johnson and Dauble (2006).

2.1 Structural Components

An SFO has an entrance structure and usually includes a conveyance structure and an outfall, as shown in Figure 2-1. Sometimes a forebay guidance structure is used to concentrate fish in the vicinity of the SFO entrance. The shape, location, and hydraulic characteristics of the entrance structure affect the forebay flow net, which is the region in which water accelerates toward the SFO entrance. The SFO flow rate may be controlled by a weir crest near the entrance, pumps, or a control gate. The most common types of gates are hinged flap gates, vertical lift gates, and radial gates (Vischer and Hager 1998). A spillway-type ogee profile, pipe, or channel is used to convey water and fish between the entrance structure and the outfall. The conveyance structure may include dewatering devices, such as screens or louvers, to reduce the amount of water necessary to pass fish. The outfall is the location where the SFO discharge enters the tailwater downstream of the dam. Environmental conditions where the outfall jet enters the tailwater are determined largely by the rate at which water is discharged, whether the discharge is submerged, skimming across the water surface, or free-falling, the height of any free-fall, the depth of the tailwater, and the location of the discharge outfall relative to shorelines (Johnson et al. 2003).

An SFO can be positioned anywhere in a hydropower project where it is desirable to draw water from the forebay to optimize fish passage. Often the entrance structure is placed where there is a concentration of fish of interest, such as in a forebay cul-de-sac (e.g., Rocky Reach Dam; Stone and Mosey 2004) or at the terminus of a forebay guidance structure (e.g., Lower Granite Dam; Adams et al. 2000). SFOs designed specifically for juvenile salmonid passage have been installed in forebays of high-head dams (>330 ft) and at powerhouses, spillways, and non-overflow sections of low-head hydropower projects.

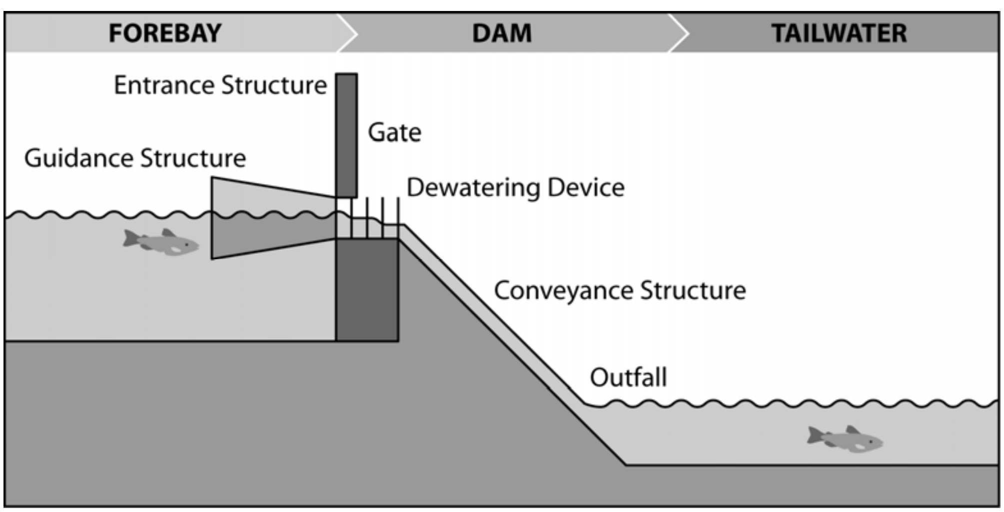


Figure 2-1. Basic components of a surface flow outlet, viewed in cross section (modified from Johnson and Dauble 2006)
(Note the free-surface flow. The guidance, gate, and dewatering structures may or may not be present. If present, the dewatering device is part of the conveyance structure.)

2.2 Entrance Flow Regime

Surface flow outlets can be categorized based on the hydrodynamic regime of flow near the SFO entrance. Specifically, SFOs fall into one of three regime categories, depending on whether the flow near the entrance is subcritical, critical, or supercritical. Critical flow occurs when the water is moving just as fast downstream as a wave propagated from a small disturbance would move upstream (Henderson 1966, page 39). This may be described mathematically as:

$$V = c, \tag{2.1}$$

where V is the free stream flow velocity and c is the wave velocity or celerity:

$$c = (gD)^{0.5}, \tag{2.2}$$

where g is the acceleration of gravity and D is the hydraulic depth of flow.

The Froude number, F, is the ratio of stream velocity to wave velocity:

$$F = V/(gD)^{0.5}. \tag{2.3}$$

The flow regime is *critical* when the Froude number is one, *subcritical* when the Froude number is less than one; and *supercritical* when the Froude number is greater than one. An example of critical flow is free overflow over a weir crest at the SFO entrance, whereas the flow controlled by an underflow gate at some distance downstream from the SFO entrance is subcritical. Flow beneath the underflow gate, however, becomes supercritical.

2.3 Types of SFOs

There are five main types of SFOs: low-flow bypass/sluice, high-flow sluice, forebay collector, powerhouse retrofit, and surface spill. Each type differs in the amount of flow, location along the hydropower dam, and type of hydraulic control gate. While some SFOs are associated with a forebay guidance device, variations include the presence of a dewatering device, the type of conveyance structure, and the type of outfall. Bioengineers use different combinations of structural features (Figure 2-2) to create an SFO, depending on site-specific concerns.

Forebay Guidance Structure	Entrance Structure	Dewatering Structure	Conveyance Structure & Outfall
Walls	Sluice	Screens	Channel
Louvers	Low-Flow Bypass	None	Ogee
Guide Nets	Forebay Collector		Pipe
Forebay Curtains	Powerhouse Retrofit		
None	Surface Spill		

Figure 2-2. Combinations of structures used in SFOs (from Johnson and Dauble 2006)

General characteristics of the five types of SFO, classified by the entrance flow regime, are as follows:

Subcritical Flow

- *Low-flow bypasses/sluices* (<500 cfs) are found at hydropower dams in rivers with relatively small discharge. They can be specially designed for a project retrofit or part of the original construction. Typically they have only one entrance measuring about 3 ft wide and 3 ft deep. They can be used in association with bar racks at turbine intakes or with louver arrays in power canals to guide fish to the entrance (e.g., the new Willamette Falls spillway bypass).

- *Forebay collectors* (200 to 6,000 cfs) are SFOs with a special structure in the forebay designed to extract fish from forebay water and convey them downstream past the dam. Forebay collectors are often deployed at high-head dams where juvenile salmonid production comes from hatcheries or natural production areas situated upstream from the dam (e.g., the forebay surface collector at Upper Baker Dam). Entrances to forebay collectors can be large (~16 ft wide and ~65 ft high).

- *Powerhouse retrofits* (1,400 to 11,000 cfs) are SFO structures built onto the forebay face of powerhouses on the Columbia and Snake rivers (e.g., the SFO at Wells Dam). The SFO entrances for powerhouse retrofits vary in size (5 × 45 ft to 16 × 70 ft) and number (1 to 5).

Critical Flow

- *High-flow sluices* (1,200 to 5,000 cfs) at dams with relatively high discharge were installed originally to manage ice and debris, but they can be used also as fish protection devices (e.g., the sluiceway at The Dalles Dam and corner collector at Bonneville Second Powerhouse). High-flow sluice SFOs may have from 1 to 6 entrances that are usually wide (10-23 ft) and shallow (3-10 ft) or deep (16-33 ft).

- *Surface spills* (usually >5,000 cfs) are surface outlets at spillways; they include notched-spill gates, surface flap gates, removable spillway weirs (RSWs), and bulkheads or stop logs to produce top spill (e.g., the RSW at Ice Harbor Dam, and modified spill bays at Rock Island Dam). There is usually just one entrance that is wide and relatively shallow (~50 ft wide and ~13 ft deep), although multiple entrances can be deployed.

Supercritical Flow

- Supercritical flow cannot occur at an SFO entrance because of the necessity of a flow control, such as a gate, to force this flow regime to occur.

The SFO types are based on general characteristics of the entrance structure. However, placing a particular SFO into a specific category can involve some subjective judgment. For instance, the Bonneville Second Powerhouse (B2) corner collector is classified as a "sluiceway" type, but it has a deep entrance, 15 ft wide by 22 ft deep. On the other hand, the Lower Granite SBC was put in the retrofit category, even though the final, best configuration possessed a single entrance 16 ft wide by 28 ft deep, similar in shape to the B2 corner collector. We support use of these SFO types to organize information with the understanding that SFO design is foremost site-specific and may not always be neatly categorized.

2.4 Conceptual Framework

The SFO conceptual framework is comprised of spatial zones and premises about smolt behavior. The conceptual framework provides a common spatial blueprint and terminology that applies across all SFO types. This will be useful when comparing features and performance of various SFOs (Chapter 4).

2.4.1 SFO Zones

The framework's five spatial zones correspond to different hydraulic regimes and fish behaviors. These zones cover juvenile salmonid migration from where the fish first enter the forebay until they pass into an SFO entrance structure and are conveyed through the dam to the outfall in the tailrace. The forebay region has three zones (Approach, Discovery, Decision; Figure 2-3) based on general environmental conditions that juvenile salmonids might be expected to encounter as they approach a hydroelectric dam with an SFO (Dauble et al. 1999; Giorgi et al. 2000). The Conveyance and Outfall Zones are the fourth and fifth SFO zones, respectively. The size of each forebay region zone decreases as the distance to the dam decreases (Table 2-1). As more hydraulic data become available in the future, it may be worthwhile to define the forebay SFO zones in accordance with more specific hydrodynamic processes, with borders bounded by key hydraulic features (e.g., acceleration or velocity gradients). The SFO zones are described in detail below.

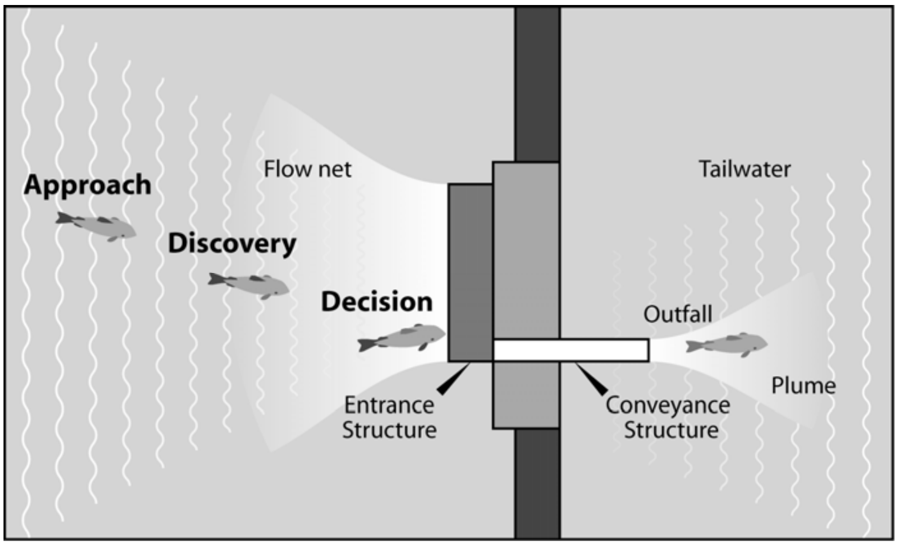


Figure 2-3. Zones in the forebay of an SFO (modified from Johnson and Dauble 2006)

Table 2-1. Distances and principal features of the zones in the SFO conceptual framework.

Zone	Distance Upstream from SFO	Principal Features
Approach	330-33,000 ft	Channel depth, channel shape, discharge, shoreline features, current pattern, temperature, total dissolved gas (TDG)
Discovery	33-330 ft	Forebay bathymetry, structures, velocity gradients (from spill and turbine loading), sound, light, temperature, TDG
Decision	0-33 ft	Velocity, acceleration, strain, turbulence, other fish, structures, sound, light
Conveyance	n.a.	Velocity, hydraulic jumps, boundary roughness, open channel vs. closed conduit flow, flow separation
Outfall	n.a.	Jet entry velocity, shear, turbulence, pool depth, eddies, shoreline, plume, TDG

The Approach Zone is the upstream extent of the forebay where juvenile salmonids first encounter the effects of the dam, roughly 330-33,000 ft from the SFO entrance, depending on SFO inflow and discharge. The thalweg is a dominant feature of river bathymetry, but does not always constitute the dominant migration path. Current patterns are mostly determined by the amount of river discharge, channel shape, and dam operations. Juvenile salmonid distribution in the Approach Zone reflects patterns found in the reservoir upstream; generally, most fish tend to be in the upper portion of the water column, with densities usually highest in the main channel or thalweg (Whitney et al., 1997). Fish movement in the Approach Zone includes both active downstream swimming and passive drift. Dams influence juvenile salmonid distribution and behavior by altering current patterns, supplying visual cues, generating sounds, and providing physical structure or habitat features not found in the upstream reservoir environment (Coutant and Whitney 2000).

The Discovery Zone is where juvenile salmonids first encounter an SFO flow net in the forebay. The flow net is the area where water accelerates toward a collection point. The Discovery Zone is 33-330 ft from the SFO entrance, but its location is highly dependent on the hydraulic characteristics of the forebay and the flow into the SFO. The physical environment in the Discovery Zone differs from that of the Approach Zone in that the forebay is typically deeper and wider. Current patterns in the Discovery Zone are variable and affected by dam operations, bathymetry, and in-water structures, such as trash booms and guidance devices. Bulk flow patterns near the dam can be complex and influenced by dam operations. Forebay macro-hydraulics in the Discovery Zone are important because this is the zone in which flow nets associated with project passage routes (e.g., turbine and SFO) begin to form. Juvenile salmonid distribution and behavior in the Discovery Zone are variable (Adams and Rondorf 2001). Vertical distribution of juvenile salmonids is mainly surface-oriented (Andrew and Geen 1960; Smith 1974). In contrast, horizontal distribution of juvenile salmonids is influenced by approach path and dam operations (Johnson et al. 2005). Juvenile salmonids can follow the main current, although some may meander or mill as they near the dam, exhibiting less directed behavior than they did upstream (Venditti et al. 2000). Turbine operations can create a strong downward or lateral flow component in the Discovery Zone. Furthermore, juvenile salmonids can pass a dam in turbine or spill flow without even discovering the SFO flow net(s).

The Decision Zone is the area immediately upstream of the SFO entrance where juvenile salmonids choose to enter or reject an SFO entrance. The Decision Zone is closest to the SFO entrance (Figure 2-3; Table 2-1). Flow here accelerates toward the entrance of the SFO structure. At SFOs installed at hydroelectric dam powerhouses, there are downward flows to the turbines beneath the SFO flow net(s). In the upper water column next to powerhouse structures, regions where water velocity is low (< 0.3 fps) may also be present. Fish response to the SFO entrance depends on factors such as light, sound, structure, and hydraulics (Larinier 1998).

The Conveyance Zone is the area where fish are transported over the dam. Structures in this zone can range from a simple ogee, such as surface spill SFOs, to a complex series of weirs, pumps, screens, pipes, and channels, such as some forebay collector SFOs. If implemented, dewatering of SFO flow typically occurs at the transition between the entrance structure and the conveyance device (e.g., the SFO at Rocky Reach Dam). The downstream terminus of the conveyance structure is the outfall.

The Outfall Zone is the area where fish are deposited into the tailrace. This zone entails the outfall structure and the entry area and SFO plume in the tailrace. In the Outfall Zone, predators can have an impact on the survival of juvenile salmonids passing in the SFO, necessitating careful design of the outfall type, orientation, and location.

2.4.2 SFO Premises

The SFO conceptual framework involves premises regarding the behavior of juvenile salmonids in each zone (Table 2-2). We revisited the premises offered by Johnson and Dauble (2006) and modified them as appropriate based on our experience developing this SFO compendium.

In the Approach Zone, fish follow bulk flow patterns as they approach a project. At sites where the bulk flow splits in different directions, the smolt population splits too, in some cases diminishing encounter with the SFO entrance location. For example, the flow split at Bonneville Dam to the B1, spillway, and B2 structures results in passage proportions that correspond to flow proportions (Ploskey et al. 2007).

Table 2-2. SFO premises related to the behavior of juvenile salmonids in response to environmental conditions at a hydropower dam with an operating SFO (modified from Johnson and Dauble 2006)

Zone	Premise
Approach	Juvenile salmonids follow the bulk flow as they approach the dam.
Discovery	Juvenile salmonids have an opportunity to discover an SFO flow net because a) vertical distribution is oriented or skewed to surface waters; b) horizontal distribution is concentrated near the SFO entrance; c) the SFO flow net has minimal competition from flow nets associated with other passage routes.
Decision	SFO entrance conditions (e.g., velocity, acceleration, turbulence, and light) do not consistently and repeatedly elicit an avoidance response before the fish are entrained.
Conveyance	Juvenile salmonids pass through the conveyance structure safely and quickly.
Outfall	Juvenile salmonids enter the tailrace without injury and rapidly migrate downstream.

The Discovery Zone premise has several components. Vertical distribution reflects natural tendencies, but can also be affected by forebay bathymetry. A surface-oriented vertical distribution and the desire to stay in the upper portion of the water column are critical for successful SFO performance. Horizontal concentration can be achieved structurally or hydraulically. The point of the relatively large forebays of many of the projects in this compendium is that a mechanism exists to funnel fish in the horizontal dimension to offer an opportunity for discovery of the SFO. The component pertaining to competing flow nets addresses simultaneous powerhouse, spillway, and SFO operations and the combined effect of the opportunity for discovery.

The Decision Zone premise reflects fish responses to environmental conditions upstream of the SFO entrance before the fish are captured. Fish behavior in the Decision Zone can make or break an SFO. This premise could be revised in the future based on detailed data on fish response to flow fields.

Within the Conveyance Zone, smolt injury and survival are typically evaluated to ensure the conduit is safely passing smolts. Generally, conveyance systems are designed to be consistent with NOAA fish passage criteria. Thus far these criteria have been useful in producing benign passage conduits.

The Outfall Zone premise is supported by considerable hydraulic modeling and field tests of jet impact on smolts (Johnson et al. 2003) and high flow outfall guidelines (PNNL et al. 2001). Except for Rocky Reach Dam, all SFOs on the Snake and Columbia rivers have high flow (> 1,000 cfs) outfalls (Appendix B).

2.5 Summary

Surface flow outlet technology entails certain basic components, including entrance and conveyance structures and an outfall. Entrance flow regimes are either critical or subcritical. For the purpose of categorization, there are four main types of SFOs in use in the Pacific Northwest: forebay collectors, powerhouse retrofits, sluiceways, and surface spills. The SFO conceptual framework contains five major spatial zones: Approach, Discovery, Decision, Conveyance, and Outfall. The SFO premises provide an understanding for reasons underlying successful and unsuccessful SFOs, as portrayed in the following SFO development synopses.

3.0 SFO Development Synopses

We prepared synopses for facilities in the Pacific Northwest where SFO technology has been applied or is being considered. Our intent was to capture lessons learned that may be applied to future SFO development at Corps and other projects. These facilities cover the gamut of Corps, PUD, and private utility projects on the mainstem Columbia, Snake, and other rivers. Methods to derive hydraulic and biological performance data are explained below. The synopses are organized by region: mid-Columbia River, lower Snake River, lower Columbia River, and other Pacific Northwest rivers (see Figure 1-1). The species of interest are typically yearling and subyearling Chinook salmon, steelhead, and sockeye (mid-Columbia River). A comprehensive list of the projects and their relevant physical features is included in Appendix B. The synopses are based on detailed material in the project descriptions (Appendix C) and the annotated bibliography (Appendix D). References for literature cited in the synopses and elsewhere in the main body of this report are contained in Appendix D, organized by project then subject matter.

3.1 Methods

3.1.1 General

The project synopses in Chapter 3 were developed to distill the information obtained from the supporting materials about each project into a succinct form to provide a common currency for comparison and from which to analyze and synthesize information and draw conclusions in Chapters 4 and 5. Each synopsis contains a description of project location, physical layout, bathymetry, hydraulic capacity, approach flow field characteristics, history of SFO development, geometry and flow characteristics of the SFO(s) developed, biological indices, and key findings from SFO investigations.

3.1.2 General Project and Hydraulic Characteristics

We gleaned a common group of data describing the physical characteristics of the projects, the project location and status, and a biological performance index from the project descriptions in Appendix C and other sources. These project data are summarized in a matrix included in Appendix B. This information includes the project location, present status of the SFO, SFO type, and a series of parameters describing the project layout, forebay, SFO, conveyance, and outfall. The flow entering the SFOs was classified by the flow regime of the entrance (subcritical or critical), as described in Section 2.2.

3.1.3 Biological Performance

To compare performance of SFOs across various projects, we developed and defined biological indices that represent SFO performance. The biological indices that follow are meant to provide information on several important behavioral mechanisms and safe passage conditions associated with an SFO.

- **Discovery Efficiency (DE)** is the proportion of smolts passing the dam that arrives near the entrance to the SFO. ("Near" is defined by the monitoring technology.) Discovery efficiency is a measure of the probability that fish encounter the flow fields created by entrance(s) to the SFO. If the SFO is located on a primary migration route, or where fish tend to congregate naturally or otherwise, then discovery efficiency can be high. This metric reflects phenomena in the Approach and Discovery zones. Standards for estimating DE do not exist; hence, the estimates do not always reflect the same spatial resolution, limiting opportunities for comparisons across SFOs.

- **Entrance Efficiency (EE)** is the proportion of fish near the SFO entrance that enter and pass through the SFO route to the tailrace. This index is meant to characterize the smolts' response to near-field attraction and entrainment conditions of the SFO. As instructive as this index appears to us, obtaining standard measures of EE at various dams proved challenging. This metric reflects phenomena in the Decision Zone. Standards for estimating EE do not exist; hence, the estimates do not always reflect the same spatial resolution, again limiting opportunities for comparisons across SFOs.

- **Fish Collection Efficiency (FCE)** is the proportion of smolts passing the dam via the SFO. FCE was the most prevalent performance index reported across investigations. It provides a broad-scale index of SFO performance, without clear direction as to what the causal mechanisms are, or whether far-field or near-field responses are at play. Even though this index is coarse, used in combination with other information collected at the dam, it can provide useful insight.

- **Fish Collection Effectiveness (FCF)** is the ratio of FCE to the proportion of total project discharge through the SFO during a given FCE study. This metric reflects the fish:flow ratio that is useful to compare to other fish passage routes, such as spill.

- **Direct Survival** is smolt survival through the main components of the SFO (entrance, conveyance and outfall). Direct effects occur in close proximity in time and space to the causative mechanism. This estimate is usually obtained using tagged smolts, where the controls are released in the immediate vicinity of the outfall, and treatment fish are either introduced near the SFO entrance, or volitionally enter it from release sites upstream from the dam.

- **Total Survival** is smolt survival through the SFO and some portion of the tailrace. Total survival reflects the combination of both *direct* and *indirect* survival/mortality. The location of control groups dictates the spatial bounds for such estimates. Often the controls are dispersed laterally across the river, typically some substantive distance (e.g., hundreds of yards) downstream from the outfall site.

We collected results from various technical reports and papers and compiled them in a master biological matrix (Appendix B) and in the project descriptions (Appendix C). Many tools have been used to study SFO performance, including underwater acoustics, telemetry, and balloon tags. The primary techniques, however, have been fixed-location hydroacoustics and acoustic or radio telemetry. The strength of hydroacoustics is large sample sizes that allow rigorous statistical comparisons of SFO configurations or operations for the run-at-large, rather than specific species. The strength of a telemetry study is detailed species-specific passage data. Often, yearly or seasonal results were presented by species. As recommended by Skalski et al. (1996), we averaged yearly data (arithmetic mean) for the purpose of the project synopses that follow. The biological data include results from 2006 and before.

3.2 Mid-Columbia River

3.2.1 Wells

Wells Dam has one of the most successful SFOs in the Columbia basin. Located at river mile 516, Wells Dam is the uppermost dam on the mainstem Columbia River through which anadromous fish can migrate. Wells Dam, shown in Figure 3-1, is an 840-MW run-of-river project with a turbine capacity of 220,000 cfs. The thalweg intersects the dam at the east embankment; accordingly, the powerhouse sits in an excavated area and has a shallow sill in its immediate forebay. The distinctive feature of the Wells Dam powerhouse is its “hydrocombine” design, with the spillway located directly above the turbine intakes. No other dam on the Columbia or Snake rivers has a hydrocombine design. The spill bay and turbine intake floors are 73 ft and 133 ft from the surface, respectively. The dam is oriented perpendicular to river flow, and includes earthen embankments on both sides of the 1,000-ft-wide powerhouse, which has 10 turbines and 11 spill bays. All 11 spill bays are equipped with leaf gates, and Bays 2 and 10 also have surface flap gates.

Douglas County PUD owns and operates Wells Dam under a license from the Federal Energy Regulatory Commission (FERC). FERC settlement agreements with state, federal, and tribal agencies mandate protection of juvenile salmonids migrating though the dam. Based on Wells' hydrocombine structure and first-hand observations of smolts using the sluiceway at The Dalles Dam and the forebay surface collector at Mayfield Dam, M. Erho (PUD Fish Biologist, retired) conceived the idea for an SFO at Wells Dam that would employ spillway baffles. In the early 1980s, the PUD performed fyke net and hydroacoustic studies that showed juvenile salmonids were generally distributed at shallow depths corresponding to the location of spill bay entrances, not the deep depths of the turbine intakes (Johnson and Sullivan 1986; Olson 1984). These data suggested turbine intake screens would not likely be a practical method to protect juvenile salmonids at Wells Dam. The potential for SFO technology, however, was recognized and pursued (Sverdrup and Parcel 1982).

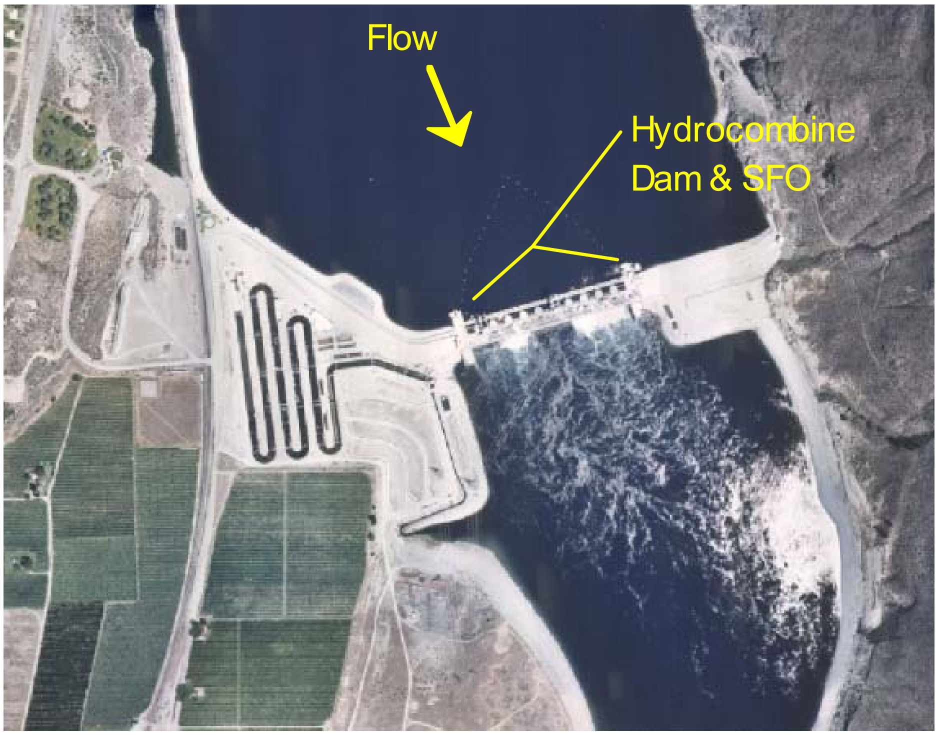


Figure 3-1. Aerial photo of Wells Dam

(See Figure 4-1 for locations of project features, i.e., SFO, spillway, and powerhouse for all aerial photos)

A prototype SFO, based on spill intake baffles that increase flow velocities in the forebay immediately upstream of the baffle opening, was first tested in 1983 at Wells Dam (Rudavsky and Oberg 1982). Mechanics attached plywood to extra trashracks and deployed them in spill bay entrance slots at Bay 10 to create a baffle prototype. (The SFO baffles are described in detail below.) Data showed that a relatively small amount of flow properly baffled is equally or more effective at passing smolts than a similar amount of flow that is not baffled (Johnson et al. 1992). The 1983 test was followed by biological evaluations of various configurations and hypotheses annually through 1989 (e.g., Sullivan et al. 1988). A two-dimensional (2-D) sectional model (1:25 scale) was used early in the SFO development to understand the flow patterns into the spill bays and turbines in their immediate forebay. Model data revealed shear zones between spill and turbine inflow that were thought to have the potential to guide surface-oriented fish toward the upper spillway rather than the lower turbines (Rudavsky and Oberg 1982). By 1990, a design for the Wells Dam SFO was finalized and the full project, permanent production system was installed. A detailed description of the development of the Wells Dam SFO can be found in Johnson et al. (1992).

The production SFO at Wells Dam has five individual bypass units. A bypass unit is formed by modifying a spill bay with sidewalls, gate slot plugs, and baffles, as shown in Figure 3-2. Sidewalls installed between the pier noses and the turbine pit walls on each side of a spill bay prevent water from flowing between adjacent spill bays, thereby increasing the effect of the intake baffles on entrance conditions. Gate slot plugs prevent flow between turbine intakes and the bypass unit. Baffles increase flow velocity into the bypass units (about 2 feet per second, fps) above the velocity that would be achieved by the same flow without baffles, because the only way for water to enter the bay when the spill gate is opened is through the baffle opening. The baffles are the most important feature in the design of the SFO at Wells Dam. After many years of testing, a vertical slot baffle opening (16 ft wide and 70 ft deep) was selected and is used today. The five SFO entrances are spaced evenly across the dam. Flow into a given bypass unit is controlled by the associated spill gate. When the bottom leaf of the spill gate at an SFO bay is raised, water enters the SFO through the baffle opening on the forebay face of the dam and exits at the spill bay ogee. There is subcritical inflow of about 2,200 cfs per unit (SFO total 11,000 cfs), with entrance velocities of about 2 fps.

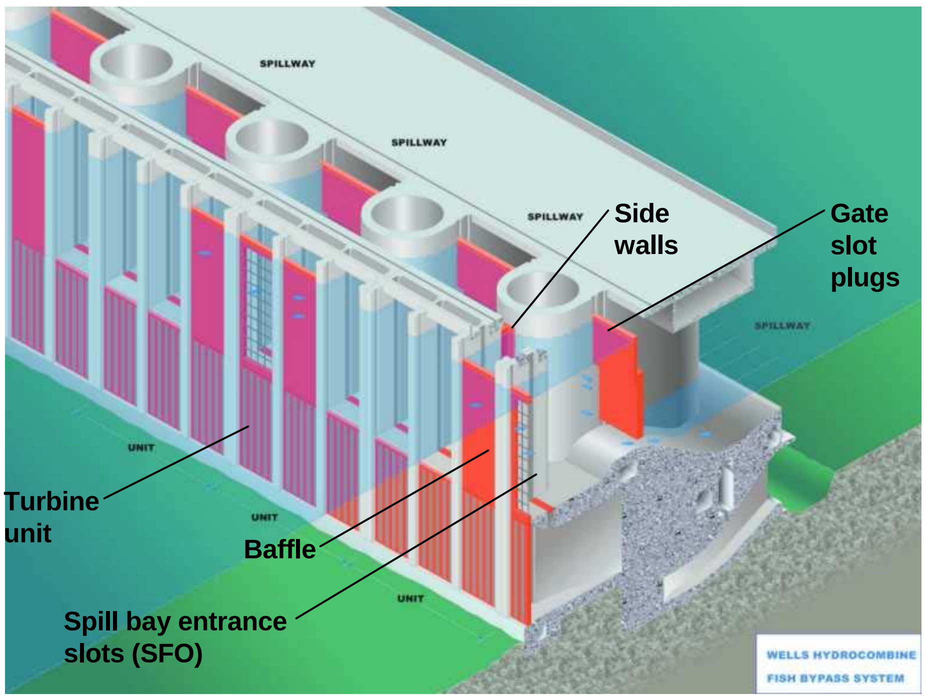


Figure 3-2. Wells Dam SFO system, vertical slot baffle opening schematic

A "Presettlement Agreement" established a goal for FCE of 80% for spring migrants and 70% for summer migrants during the 1990-1992 post-construction evaluation period. Biological evaluations (Table 3-1) using hydroacoustic techniques showed FCE averaged 89% in both spring and summer (Skalski et al. 1996). Project survival estimates from PIT tag studies during 1999-2001 averaged 96.2% (± 3.0%) (provided by R. Klinge, Appendix C). This result was calculated from 1998 data for yearling Chinook salmon (99.7% ± 2.9%), 1999 data for steelhead trout (94.3% ± 3.1%), and 2000 data for steelhead trout (94.6% ± 2.9%).

Like any fish bypass, the SFO at Wells has strengths and weaknesses. Some strengths are that Wells' SFO is highly efficient; was relatively inexpensive to build, install, and operate; uses a relatively small percentage of the powerhouse capacity (≤ 5 %) so impact to power production is acceptable and total dissolved gas (TDG) is not increased; and fish are not handled, collected, or held. There is, however, some loss in power production when river flows are less than powerhouse plus SFO flow capacity, as is the case for all SFOs. Discussions in 1995 with developers of the SFO at Wells Dam revealed important lessons (Johnson 1995), including that fish cannot be made to do something they do not want to do, and they will avoid turbines if they have an alternate route of passage in the upper part of the water column at the powerhouse. A small amount of spill that is baffled to provide an attraction flow field is as or more effective at passing fish than a similar amount of spill that is not baffled, because baffling concentrates inflow to the SFO, creating a flow field that fish apparently discover and use to pass through the dam.

Table 3-1. Biological performance indices for the Wells retrofit SFO.

(FCE and effectiveness data are from 1990-1992. Survival data are from 1998-2000.)

Species	Fish Collection Efficiency	Fish Collection Effectiveness	Total Survival Rate
Yearling Chinook	---	---	1.00
Steelhead	---	---	0.95
Run-at-Large Spring	0.89	17.89	---
Run-at-Large Summer	0.89	17.79	---

The SFO at Wells Dam is a success because it provides a passage route in the upper water column where smolts are naturally distributed and because smolts generally do not to sound to pass the dam. Key findings from Wells Dam include:

- Wells' hydrocombine structure allows multiple SFO discovery opportunities because there are several SFO entrance openings placed uniformly across the powerhouse in the upper water column above deep (80-ft) turbine intakes.

- Juvenile salmonids are concentrated horizontally at the dam because the hydrocombine design necessitates that the entire river flow be discharged through an area about 1,000 ft wide; this increases the likelihood of SFO discovery at Wells Dam.

- Juvenile salmonids were distributed in the upper 35 ft of the water column as they approached the project in the shallow forebay upstream of the powerhouse (Johnson 1996). Depth, not water velocity, was the most important factor explaining variation in smolt density in the forebay of Wells Dam (Johnson 1996).

- Baseline vertical distribution data show that, depending on species and day/night, 63%-94% of the sockeye and Chinook salmon smolts were distributed above the SFO entrance floor 70 ft deep (Johnson et al. 1992), meaning they should be able to discover the SFO flow net.

- Although discovery and entrance efficiency were not directly estimated during SFO development studies at Wells Dam, these metrics must be at least 89% on average because FCE for both spring and summer was 89% in the 3-year total project passage evaluation during 1990-1992 (Skalski et al. 1996).

- Baffling can be used to create SFO flow nets and entrances that smolts will use. That is, once in the SFO flow net, juvenile salmonids will pass into an SFO entrance 16 ft wide and 70 ft deep with a mean entrance velocity of 2 fps.

- The retrofit SFO at Wells Dam with the conveyance and outfall structures including bottom spill ogees is safe for fish, as evidenced by total survival rates of 95% for steelhead and 100% for yearling Chinook salmon.

- The SFO at Wells Dam works because it takes advantage of the hydrocombine structure and smolt behavior. This is an example of the site-specific nature of SFO development.

3.2.2 Rocky Reach

The Rocky Reach Hydroelectric Project, on the Mid-Columbia River north of Wenatchee, Washington, is owned and operated by Chelan County PUD. The dam, shown in Figure 3-3, has a Z-configuration with the spillway located upstream from the 220,000-cfs hydraulic capacity powerhouse, which is parallel to the river thalweg. A large eddy forms at the downstream end of the cul-de-sac formed by the powerhouse and the downstream forebay wall.

Figure 3-3. Aerial photo of Rocky Reach Dam

Biological data in the 1980s indicated that few juvenile fish passed the project in spill and the majority passed through the downstream units of the powerhouse near the forebay wall in the vicinity of the eddy (e.g., Steig and Sullivan 1991). Attempts to develop intake diversion screens in the downstream units in the late 1980s and early 1990s were not as successful as desired (Peven and Abbot 1994; Steig 1993). The flow pattern and biological data led to the conclusion that an SFO located near the downstream end of the cul-de-sac might be successful (Peven and Abbot 1994). Physical hydraulic modeling was used to select the best location for a forebay collector entrance along the periphery of the forebay eddy (ENSR 1995, 1997, 1998). A prototype forebay collector with a subcritical flow entrance withdrawing approximately 1,500 to 2,000 cfs flow at velocities that matched those in the forebay eddy, with flow driven by both pumping and withdrawal by venturi action into the downstream turbine through dewatering screens, was installed in 1995 (Peven and Abbott 1994). The 1995 prototype passed approximately 900,000 fish, as estimated by video counts (Peven et. al. 1995). The prototype collector was incrementally modified with the aid of physical hydraulic modeling (ENSR 2001) and tested through 2000, with several important findings over the years of prototype testing.

- Flow deceleration occurred just downstream from one of the prototype collector entrances. Under this condition substantial numbers of fish that had entered the collector retraced their route and exited through the entrance. The deceleration was corrected; which minimized the rejection problem (Peven and Mosey 1999).

- A horizontal platform was installed at floor level in front of the entrance in an effort to guide the surface-oriented fish into the entrance. However, a decrease in collection efficiency for some species was observed. It appeared as though some fish were avoiding the flow field that was accelerating downward in front of the platform, and were carried into the eddy rather than the entrance. The platform was removed, increasing collection efficiency (Adenyi et al. 1998).

- A second entrance was added upstream from the first entrance, with both entrances withdrawing 3,000-cfs flows each at eddy velocity. The additional entrance did not increase overall FCE, but rather split the collection between the two entrances. Varying the width of the second entrance did not improve efficiency either (English et. al. 2000, Steig and Timko 2000). The second entrance was subsequently removed.

Intake diversion screens in the downstream turbine units are a separate component of the juvenile fish bypass system (ENSR 2001). The intake screens were improved in parallel with SFO development; however, we do not address intake screen performance in this document. In 2003, a production SFO was constructed that is similar in concept to the final prototype, but with a single 6,000-cfs subcritical flow entrance, as shown in Figure 3-4.

Commencing in 2004 a multi-pronged biological evaluation program of the Rocky Reach SFO was undertaken using miniaturized acoustic-tags surgically implanted in smolts. The program included behavioral, FCE, and survival estimation studies. Appendix C presents the annual estimates of performance indices for each species. The studies presented here have been compressed by averaging across years. This distillation gives an overall assessment of SFO performance from 2004-2006 (Table 3-2).

FCE for steelhead was high, with 67% of the fish passing the dam using the corner collector. FCE decreased substantially for sockeye and yearling Chinook salmon, with only 37% and 30% of the tagged smolts passing through the corner collector. The worst performance was exhibited by subyearling Chinook salmon, with only 25% passing through the SFO.

Reliable estimates of discovery efficiency and entrance efficiency are available only for sockeye salmon because the processing technique to provide these estimates was improved during recent studies in which only sockeye were tagged. We do not report data from previous years for steelhead and yearling Chinook salmon because the spatial resolution was not well defined. We could not readily interpret the discovery efficiency and entrance efficiency estimates for subyearling Chinook salmon as reported for only one year, and thus cannot use them in this application.

Table 3-2. Biological performance indices for the Rocky Reach forebay collector.

(Results are averages over data obtained during the years 2004-2006.)

Species	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Direct Survival
Yearling Chinook	---	---	0.30	---
Steelhead	---	---	0.67	---
Sockeye	0.41	0.89	0.37	0.97
Subyearling Chinook	---	---	0.25	0.97

Survival through the SFO was only evaluated for two species, sockeye and subyearling Chinook salmon. Overall, survival from a release site at the upstream end of the SFO to entry in the tailrace was high, at 97% for both species (Skalski et al. 2005).

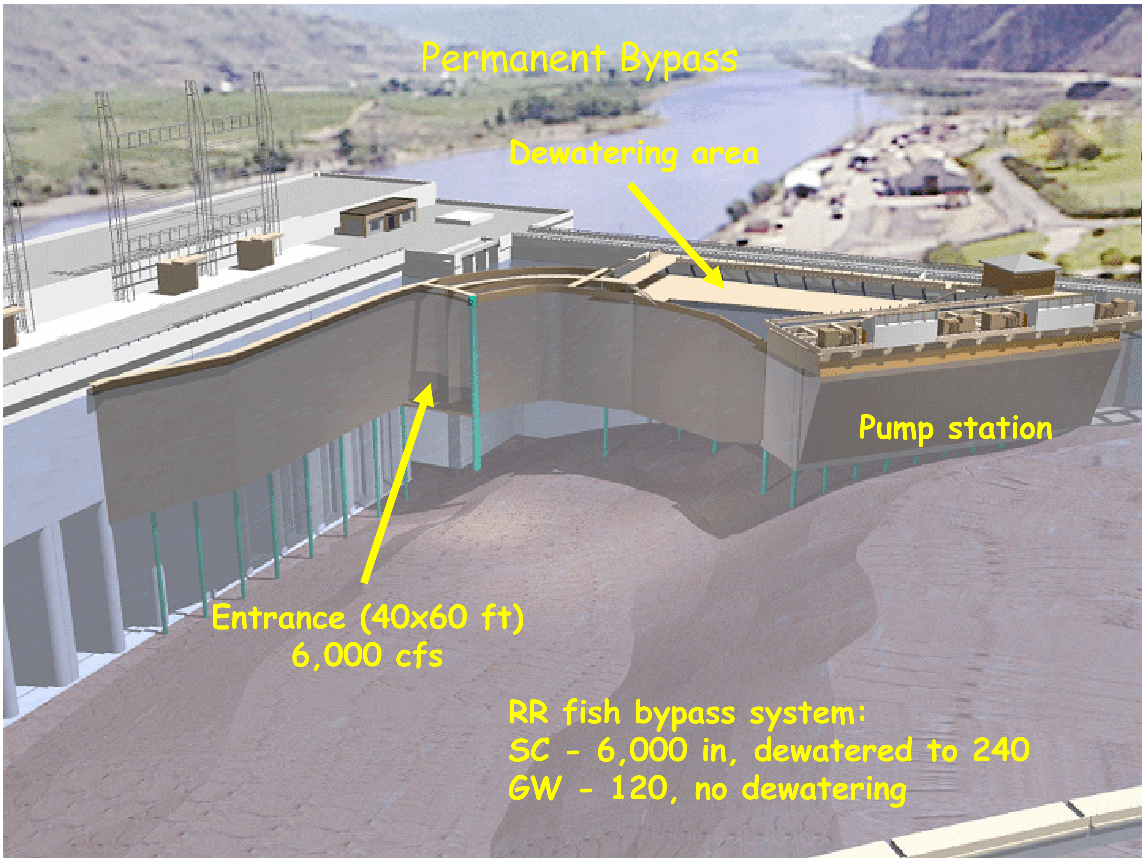


Figure 3-4. Rocky Reach Dam permanent forebay collector SFO

The Rocky Reach corner collector SFO is operated on a routine basis to pass downstream migrants while investigations are ongoing to improve its performance. Key findings from the substantial number of studies conducted during SFO development at Rocky Reach Dam over the last decade are:

- The pronounced large eddy formed in the cul-de-sac of the powerhouse allowed the strategic placement of an SFO entrance to intercept smolts as they moved near the powerhouse.
- FCE varies widely (25-67%), depending on the species (Steig et al. 2007). This appears to be largely a result of species differences in vertical distribution in the forebay. Deeper migrating species (e.g., sockeye) are more likely to enter turbine intakes that they pass by en route to the SFO, which is situated near the terminus of the cul-de-sac. Shallower migrating species (e.g., steelhead) exhibit relatively high FCE (Steig et al. 2007).
- Once they have discovered it, smolts will readily enter an SFO entrance 40 ft wide (partitioned into 2 parallel channels) and 60 ft deep with a mean entrance velocity of 2.5 fps and inflow of 6,000 cfs. However, flow deceleration downstream of the entrance opening can cause rejection for some species and should be avoided (Peven and Mosey 1999). This may be particularly important if trapping velocities have not been achieved upstream from the deceleration zone.

- The 6,000-cfs inflow is dewatered to 240 cfs using a ramp and louver structure that successfully passes smolts downstream without rejection. This provides proof-of-concept for large scale dewatering.

3.2.3 Rock Island

The Rock Island Hydroelectric Project is located on the Mid-Columbia River southeast of Wenatchee, Washington. The dam is owned and operated by Chelan County PUD. The forebay of the project is divided in two by "Rock Island", as shown in Figure 3-5. A central spillway straddles the island, and there are two powerhouses, one at each shoreline. Flow splits to either side of the island to supply the powerhouses. Eddies form at either side of the island and progress downstream in the flow approaching the spillway that straddles the island. The older, east bank powerhouse (PH1) has Kaplan turbines, while the west bank powerhouse (PH2) employs horizontal axis bulb turbines. Intake screens were tested at PH2 in 1988 and PH1 in the 1990's, but were not considered successful (Peven and MacDonald 1994). The screen systems were abandoned in the mid-1990's in favor of spill for passing juvenile salmonids.

Figure 3-5. Aerial photo of Rock Island Dam

Downstream fish passage through spill via the regular vertical lift underflow gates, surface overflow spill gates, a surface over/under configuration, and notched top spill gates has been investigated using telemetry and hydroacoustic techniques (Iverson et al. 1999). In addition, both numerical (computational fluid dynamics, CFD) and physical hydraulic modeling has been conducted (District Staff 1995). Prototype tests of surface flow spill gates with different configurations showed that the spill gates are preferred passage routes (e.g., Iverson et al. 1996). All prototype spill configurations (overflow, over/under flow configuration, and notched spill gates) had a critical entrance flow regime.

Flow from the spill gates impinges on a rocky shelf downstream. The submergence of the rock formation varies with spill bay, with shallower or exposed rock near the island formation at the middle of the spillway.

Additional studies have been performed to determine the injury/mortality probability of fish passing through various spill bays (Skalski et al. 2000). Modification of the downstream rock bathymetry to provide a "landing pad" for fish spill to minimize injury potential has also been investigated (Normandeau and Skalski 2000).

Numerous studies at Rock Island Dam since about 1982 have evaluated the passage behavior of juvenile salmonids. The most efficient method of bypass at Rock Island Dam appears to be offered through top spill (Ransom and Steig 1995). At Rock Island Dam top spill can be regulated at each spill bay by two or three crest gates that are stacked one on top of the other. The crest gates are 30 ft wide and 11 or 22 ft high, and discharge is controlled by lifting these gates. In 1996, the District began testing the effectiveness of different surface spill gate designs (notched spillgate, overflow spillgate, and overflow weir) to bypass fish through the spillway at Rock Island Dam. The results showed that notched spill gates passed significantly more fish per unit of flow than overflow gates (Iverson et al. 1996). A photo of top spill at Rock Island is shown in Figure 3-6.

Figure 3-6. Top spill at Rock Island Dam

In 1997, direct survival estimates for different spill gate designs were obtained using balloon-tagged, hatchery-reared Chinook salmon (Normandeau and Skalski 1998). The direct survival through a modified notched weir and an unmodified spill bay was estimated at 95% and 98%, respectively (Table 3-3). Reduced survival through the notched weirs may have resulted from the very shallow stilling basin below the test bays, and the reduced discharge through the notched weirs. The researchers noted that some of the fish passing the notched weir impacted the concrete apron present at Spill Bays 21-23 in the tailrace at the lower discharge rate (1,000 cfs), as compared to 10,000 cfs discharged through the unmodified spill bay (Normandeau and Skalski 1998). Subsequent survival estimates through both modified and unmodified spill bays were between 99.5% and 100% when water was discharged through spill bays without a concrete apron (Normandeau and Skalski 2000). Similar results obtained for the entire spillway from route specific survival studies suggest total survival for steelhead and yearling Chinook was between 98% and 100% (Lady et al. 2000; Skalski and Townsend 2005).

Recently, Chelan County PUD began testing a prototype over/under spill gate configuration (Normandeau and Skalski 2005). The purpose of the prototype over/under spill configuration is to provide migrating juvenile salmon with an SFO that limits the generation of dissolved gas associated with plunging flows. The direct survival estimate for four of the test groups (aerated center, aerated edge, non-aerated center, and the special test of non aerated edge uncapped) were all nearly 100% except for the non-aerated edge condition, which resulted in a survival estimate of 98%.

Estimates of discovery, entrance, and FCE have not been obtained for the specific spill gate design configurations. However, estimates for FCE for the entire spillway have been generated for some juvenile migrants (Table 3-3). We caution that these FCE estimates are a generic index of the biological performance of the entire spillway and the mix of spill bay configurations at the time of testing. We compressed estimates by averaging across years FCE was estimated (Lady et al. 2000; Steig et al. 2006a and 2006b). FCE of the Rock Island spillway for steelhead was 22% of the fish passing the dam. Spillway FCE for yearling Chinook salmon was 37% for tagged smolts passing through the dam. Sockeye salmon, on average, had the highest spillway FCE at 42%. FCF ranged from about 1.0 for steelhead to about 2.0 for sockeye. The target spill percentage at Rock Island is 20% according to the Habitat Conservation Plan; this target has been achieved within 0.2% every year since 2003 (S. Hemstrom, personal comm.).

Table 3-3. Biological performance indices for the spillway at Rock Island Dam.

(FCE estimates are averages over data obtained during the years of investigation: 1999, 2004, and 2005; survival estimates are from 1997 and 2005.)

Location	Species	Fish Collection Efficiency	Direct Survival	Total Survival
Notched weir spill bay	Yearling Chinook	---	0.95	---
Standard spill bay	Yearling Chinook	---	0.98	---
Notched weir spill bay	Yearling Chinook (ROR)	---	1.00	---
Standard spill bay	Yearling Chinook (ROR)	---	0.99	---
Prototype over/under gate	Yearling Chinook	---	0.98-1.00	---
Entire Spillway	Yearling Chinook	0.37	---	0.98-0.99
	Steelhead	0.22	---	1.00
	Sockeye	0.42	---	---
	Run-at-Large Spring	0.28	---	---
	Run-at-Large Summer	0.33	---	---

Opening notched spill gates is the routine operation to protect juvenile salmonids migrating through Rock Island Dam. Key findings and observations that we distilled from the SFO studies conducted at Rock Island include:

- FCE at the spillway (primarily surface bays) varies by species, with steelhead (22%) ranked lowest and sockeye (42%) ranked highest according to our index approach. Targeting spill at 20% of river discharge provides different spill passage efficiency for each species.
- Survival through the surface spill bays was high (98-99%) once the operations were tailored to minimize smolt impact in shallow zones in portions of the stilling basin (Skalski and Townsend 2005).
- Notched surface spill gates passed significantly more fish per unit of flow than overflow gates (Iverson et al. 1999).

3.2.4 Wanapum

The Wanapum Hydroelectric Project, owned and operated by Grant County PUD, is located on the Columbia River near Beverly, Washington. It has a Z-dam layout, shown in Figure 3-7, and a 118,300-cfs hydraulic capacity powerhouse. Development of methods besides spill to enhance the passage and survival of juvenile salmonids commenced in 1984 with the testing of a diversion net to divert smolts away from the powerhouse toward the spillway (BioSonics 1985). Lack of success with the diversion net was followed by testing of wedge-wire diversion screens in turbine intakes from 1990 to 1994 (Ransom et al. 1998). The screens were discontinued due to concerns about descaling, impingement, and stress. The success of the SFO for fish passage at Wells Dam influenced Grant County PUD to assess whether a similar bypass strategy could have merit, with SFO entrances located above powerhouse intakes at Wanapum Dam.

Wanapum SFO development started in 1994. A physical model of a single powerhouse unit was used to test the alignment of a slot relative to the face of the powerhouse (Weber et al. 1994). In 1995, a surface attraction channel (SAC) was constructed in front of powerhouse Units 7, 8, and 9, with a vertical bypass slot centered on Unit 8. Inflow (280-1,400 cfs) was controlled by pumps. The conveyance structure included dewatering screens and a pipe to convey fish to a low flow outfall in the tailrace. The SAC was tested with various entrance widths and depths, but FCE was very low (< 1%) for all configurations, as indicated by hydroacoustic data (Kumagai et al. 1996; Table 3-4). The SAC was modified in 1996 and 1997; however, FCE remained low, possibly because deceleration in the flow approaching the SFO entrance caused rejection, and juvenile salmonids approaching the SAC in the large Wanapum forebay apparently had difficulty discovering the SFO entrance. The SAC was eventually discarded as an SFO design option.

Another SFO investigation at Wanapum concerned the sluiceway. Historically, the 20-ft wide ice and trash sluiceway adjacent to Spill Bay 12 passed about 3-6% of total smolt passage at the dam, with a flow of about 2,000 cfs (Table 3-4). Mean FCE estimated for the sluiceway during several years of testing between 1989 and 1996 was about 6-7% for both spring and summer migrants past Wanapum Dam (Ransom 1997). Total passage survival for steelhead was 93% through the sluiceway (Smith et al. 2000). The relatively high effectiveness of the sluiceway, which used approximately 2,000 cfs, or less than 2% of the powerhouse hydraulic capacity, and the observed survival for fish passing this route led to the question of whether survival could be improved by passing the fish and flow through an SFO with vertical slot entrances rather than the existing broad-crested weir at the sluiceway.

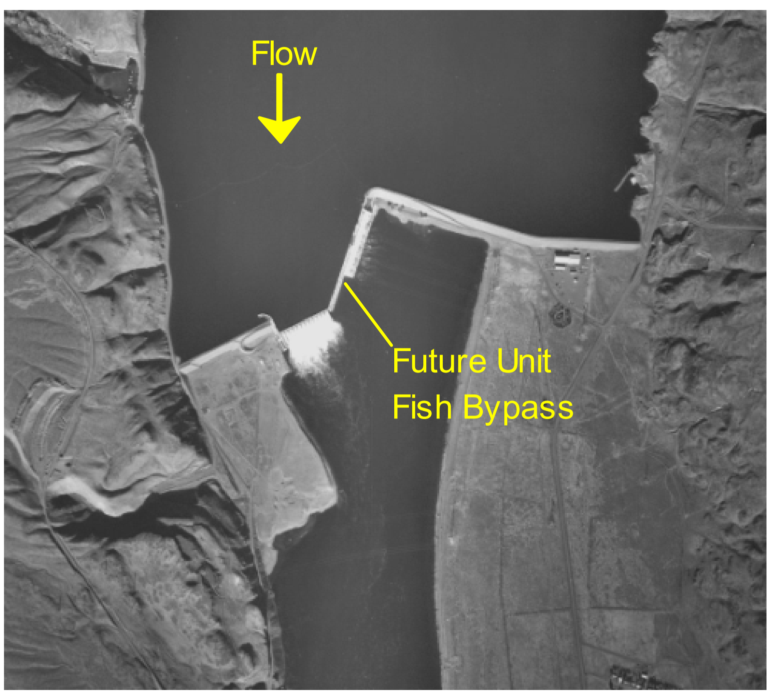


Figure 3-7. Aerial photo of Wanapum Dam

Table 3-4. Biological performance indices for the Wanapum SFO

(FCE estimates are averaged over data obtained during the years of investigation; see Appendices B & C for source data.)

SFO	Species	Fish Collection Efficiency	Direct Survival	Total Survival
SAC	Run-at-Large Spring	0.003	---	---
	Run-at-Large Summer	0.003	---	---
Sluiceway	Run-at-Large Spring	0.06	---	---
	Run-at-Large Summer	0.07	---	---
	Yearling Chinook	0.03	---	0.90
	Steelhead	---	---	0.93
Slotted Top Spill	Yearling Chinook	0.17	0.95	0.94

A top-spill bulkhead with vertical slotted openings was investigated using a physical hydraulic model in 1995, and was prototype tested in Spill Bay 12 in 1996 and in Spill Bay 10 in 1997. The tested SFO flows were 2,000 and 4,000 cfs and the entrance flow regime was critical for both flows. In 1996, a hydroacoustic study indicated that about 11% of the fish passing the project during the spring used the slotted bulkhead, although the percentage of fish passing through the ice and trash sluiceway was reduced (Birmingham et al. 1997). Balloon tag tests estimated direct survival of 92% when discharging 2,000 cfs and 96% while discharging 4,000 cfs (Normandeau et al. 1996a). The slotted top-spill did not have satisfactory flow control and the hydraulic conditions between the bulkhead and face of the Tainter gate were not adequate; hence, this design was discarded. It was also thought that larger SFO inflows may be required to achieve the FCE required for the project by FERC, an efficiency level that probably could not be readily achieved through the vertical slots at the sluiceway.

SFO development continued at Wanapum in the 2000s. A study team comprised of PUD staff, agency personnel, and consultants was formed in 2001 to plan, construct, and test an 11,000-cfs top spill SFO in Spill Bay 12. This team also assessed alternative SFO concepts, with input from field data, model studies, and premises of fish behavior. The team compiled a report on the fish passage alternatives study that identified and ranked thirteen basic alternatives (Jacobs et al. 2004). The alternative selected for design development and evaluation was a concept that routed bypass flow through a free-surface outlet at one of the future unit skeleton bays adjacent to the powerhouse. To begin development of the recommended SFO, called the future unit fish bypass (FUFB), hydraulic and CFD models were used in 2003-2006 to test concepts and develop a final design for a fish bypass adjacent to the powerhouse in a skeleton bay originally set aside for future powerhouse units. The physical models were used to determine the hydraulics of the approach flows, zone of influence, and flow competition with the powerhouse. Also, physical models were used to examine hydraulic conditions in the tailrace with respect to fish egress, TDG concentrations, and riverbed erosion (Haug et al. 2003; Lyons et al. 2005). In 2004, a 32-ft-wide, 38-ft-deep notched bulkhead was modeled and prototype tested in Spill Bay 12 with a nominal flow of 20,000 cfs to duplicate the critical entrance flow regime and design flow for the FUFB. These prototype tests were used to assess potential FCE for the FUFB. Researchers also assessed whether fish rejected a bypass opening where all the acceleration up to trapping velocity occurred within the forebay. Biological results from an acoustic telemetry study showed no apparent rejection of the top spill opening, and the major approach path was along the face of the future units (Robichaud et al.

2005a,b). Also in 2004, a modification to the trash and ice sluice was designed, confirmed through physical hydraulic modeling, and field tested to evaluate fish survival under exit conditions intended to simulate those of the FUFB.

In the final FUFB design (shown in Figure 3-8), the SFO is located adjacent to powerhouse unit 10 and is designed to pass 20,000 cfs at normal pool with all gates fully open, and will be able to pass regulated top spill flows of 2,000, 5,000, 10,000 and 15,000 cfs. The SFO opening will have an entrance velocity at the dam face of 12.75 fps for full bypass flow. The SFO outfall will be located adjacent to turbine flows to facilitate egress of the smolts in the mid-channel area. The discharge will be elevated and spread to a 90-ft width to minimize TDG and river bed scour. The final design was selected based upon the prototype evaluation, and construction of the FUFB commenced in 2006. It is expected that the FUFB will achieve success as it utilizes a significant flow, relative to powerhouse capacity, is designed to provide an approach flow field that emulates the successful top-spill prototype tests, and is located along the expected migration path of fish that pass the powerhouse and move toward the spillway.

At Wanapum Dam, a full production FUFB is under construction and is scheduled for completion and biological testing in 2008. Key observations from studies conducted at Wanapum Dam include:

- Studies of a retrofit SFO, called the surface attraction channel, in the 1990s revealed low FCEs (0.3%; Kumagai et al. 1997). Low FCEs were likely due to lack of encounter with the SFO flow net, although discovery efficiency was not explicitly estimated.

- Smolts used the sluiceway and prototype surface spill SFOs, but the project-wide FCEs were not high (3%-6%; Ransom 1997; Robichaud et al. 2003).

- The absence of a known migration pathway or features that can concentrate or direct smolts toward a specific location is a disadvantage, and can result in low discovery of the SFO entrance.

- Baseline acoustic telemetry data revealed a "major" migration pathway along the face of the powerhouse in front of the future units where the new retrofit SFO is to be installed in 2007-2008 (Robichaud et al. 2005).

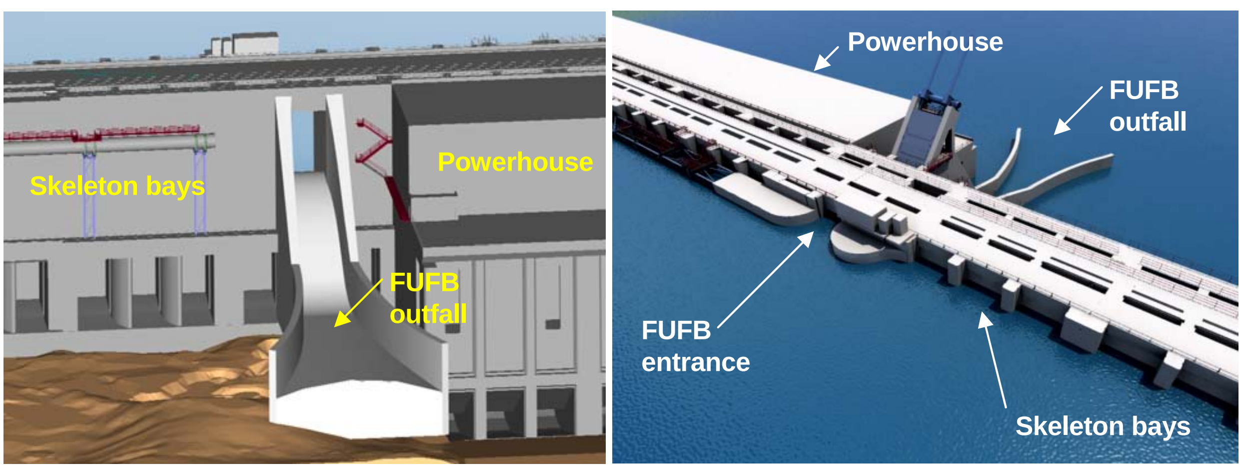


Figure 3-8. Wanapum future unit fish bypass schematics

3.2.5 Priest Rapids

Priest Rapids Dam, which was completed in 1961, is located on the Columbia River at RM 397. It is owned and operated by Grant County PUD. This linear dam, shown in Figure 3-9, is oriented perpendicular to river flow and consists of both earth embankment and concrete sections that span approximately 7,500 ft across the river. The powerhouse contains ten Kaplan turbines. The spillway consists of 22 Tainter gates that produce a bottom spill at a depth of 52 ft. The 22nd gate, located adjacent to the powerhouse, is typically used as a top spill sluiceway capable of discharging 3,000 cfs. Downstream juveniles must pass Priest Rapids Dam either through the turbines, spillway (including sluiceway), or via gatewell dipnetting. There are currently no juvenile passage facilities operating at Priest Rapids Dam.

Biological performance indices have focused on passage through the only surface route, the sluiceway. Ransom (1997) summarized mean estimates of FCE for 24-hr sampling periods produced from hydroacoustic studies conducted in 1990's. Data from those years indicated that FCE for spring migrants at the sluiceway was 5%, and summer migrant FCE was 4% (Table 3-5). In 2001, the FCE estimate obtained from radio tagged yearling Chinook was 2% (English et al. 2001). The survival estimate for fish passing the sluiceway was estimated at 89% in that same radio telemetry study.

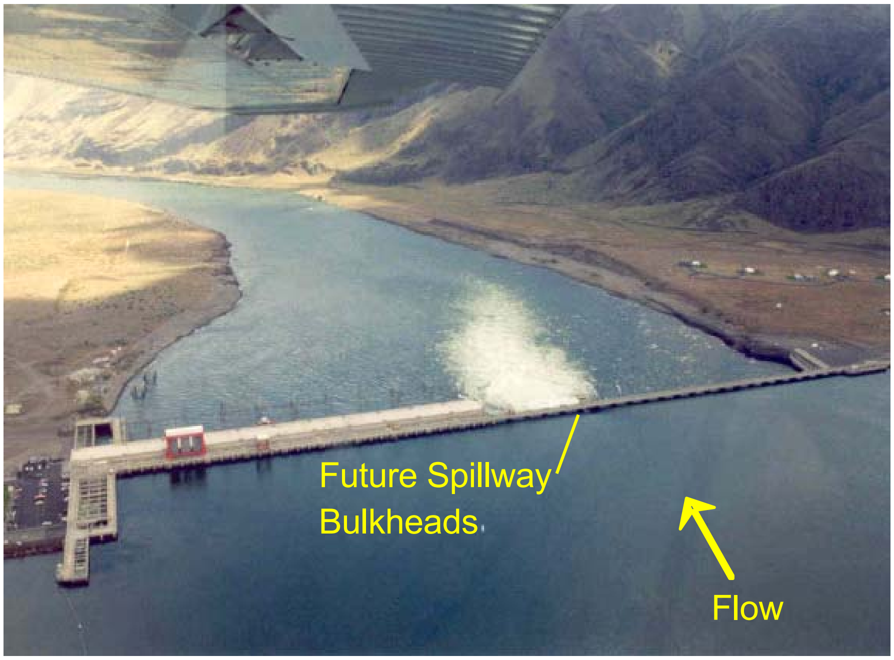


Figure 3-9. Aerial photo of Priest Rapids Dam

Table 3-5. Biological performance indices for Priest Rapids Dam sluiceway.
(Data are from 1992, 1994-1996, and 2001-2003.)

Species	Fish Collection Efficiency	Total Survival
Run-at-Large Spring	0.05	---
Run-at-Large Summer	0.04	---
Yearling Chinook	0.02	0.89

Application of SFO technology is currently being considered for Priest Rapids Dam (Voskuilen et al. 2003). The same design team that developed the SFO concept under construction at Wanapum Dam is transferring the findings of their research and development work to Priest Rapids. Modeling studies are presently underway to develop an SFO prototype test facility at the spillway at Priest Rapids. An artist's rendering of this SFO, a spillway bulkhead with a critical flow entrance, is shown in Figure 3-10.

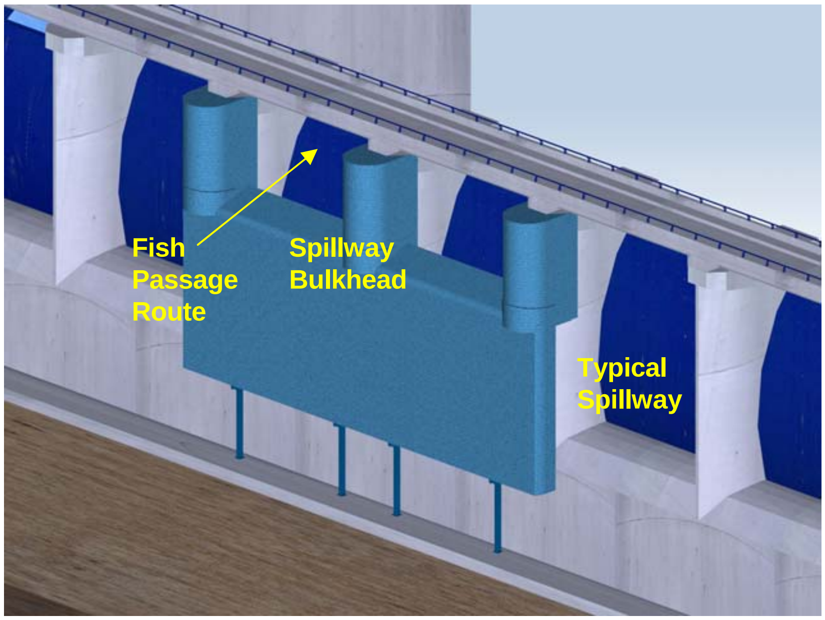


Figure 3-10. Priest Rapids spillway bulkhead SFO schematic

3.3 Lower Snake River

3.3.1 Lower Granite

Lower Granite Dam has been at the forefront of SFO development in the Pacific Northwest. Completed in 1975 by the Walla Walla District of the Corps, it is the fourth dam on the Snake River, 107 miles upstream from the Columbia River confluence. The dam, shown in Figure 3-11, is oriented perpendicular to river flow and includes a powerhouse, a spillway, a navigation lock, and an earthen section. The 650-ft-long powerhouse has six turbine units, a hydraulic capacity of 130,000 cfs, and a generating capacity of 810 MW. The 500-ft-long spillway has eight spill bays, each with a radial gate. The thalweg runs through the center portion of the project. The Corps concluded in the Lower Snake River Feasibility Study (under Major System Improvements; USACE 2002) that SFO technology was warranted to improve juvenile fish passage through the hydropower corridor. Encouraging fish passage results from the Wells Dam SFO and sluiceways at Bonneville, Ice Harbor, and The Dalles dams provided the impetus for SFO development at Lower Granite Dam, which was a priority in the Corps' Surface Bypass Program. Two major SFO development efforts have occurred at Lower Granite Dam: 1) the Surface Bypass and Collector with associated Simulated Wells Intake and Behavioral Guidance Structure, and 2) the Removable Spillway Weir (RSW).

The Surface Bypass and Collector (SBC), in place during 1996-2000, was a partial-powerhouse prototype retrofitted onto the forebay side of Turbine Units 4-6. The SBC is shown in sectional view in Figure 3-12. This temporary test structure was designed to collect juvenile salmon that would otherwise have passed into

Turbine Units 4-6. The focus was on studying attraction and collection of juvenile salmon from the forebay, since many other SBC features, such as the outfall, would likely be different in a final, full powerhouse design. Large flotation chambers allowed the structure to move vertically as the water surface elevation of the forebay changed (range about 5 ft). The SBC, essentially an elongated steel channel 60 ft high, 20 ft wide, and 330 ft long, was connected to Spill Bay 1, where the radial gate controlled SBC inflow. Subcritical flow entered the SBC through entrances on the upstream (forebay) side of the channel and exited through Spill Bay 1 into the dam's tailrace. Opening or closing particular doors of the SBC entrances formed specific configurations for testing purposes. Maximum discharge through the SBC was 3,500 cfs; this flow was not dewatered.

Figure 3-11. Aerial photo of Lower Granite Dam

Two noteworthy structures were added to the SBC in 1998 to improve FCE, the Simulated Wells Intake (SWI) and the Behavioral Guidance Structure (BGS). The SWI was retrofitted to the bottom of the SBC, effectively changing the roofs of the intakes at Turbine Units 4-6 from 50-ft deep with gradual roof slopes to 70-ft deep with abrupt horizontal roofs that extended through the trash racks into the intake itself. See the SBC profile in Figure 3-12. This retrofit was done to try to decrease the entrainment of juvenile salmon downward to the turbines, thereby increasing their availability to the SBC. The SWI was designed to match as close as possible the Wells Dam flow line approach and intake roof shape/depth. The BGS, a floating wall 1,100 ft long and 55-80 ft deep, was attached to the dam at the south end of the SBC. It extended at an oblique angle toward the southern shoreline of the forebay. The BGS was designed to alter the horizontal distribution of juvenile salmon as they approached the powerhouse by diverting downstream migrants to the north away from Turbine Units 1-3 and toward the SBC and spillway.

Hydraulic evaluations of the SBC, SWI, and BGS included extensive physical scale and numerical modeling and field measurements (CH2M-Hill 2000; USACE 2000). Field measurements were taken with an Acoustic Doppler Current Profiler (ADCP) for general flow approach information and an Acoustic Doppler Velocimeter (ADV) for specific entrance flow rate and turbulence information (HDR and ENSR 2000). Six physical models (e.g., 1:25, 1:40, and 1:80 scales) were used to evaluate different design components and project operations. Numerical models were applied to provide detailed hydraulic analysis related to both new designs and existing features. The hydraulic evaluations were used to determine SBC entrance configurations and flow fields; the depth, length, angle, and attachment point for the BGS; and the shape and location of the SWI.

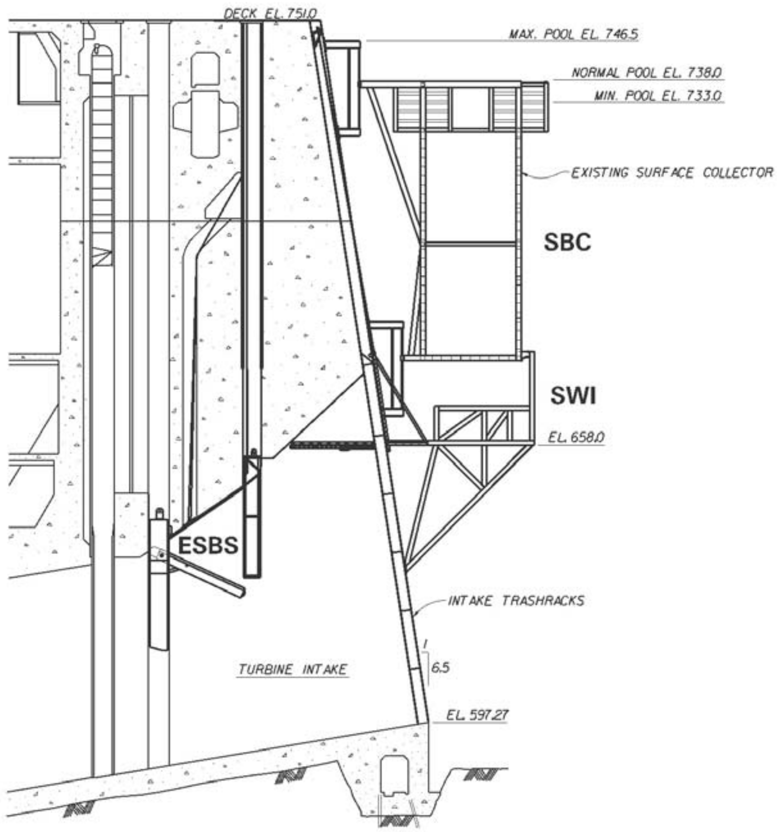


Figure 3-12. Lower Granite SBC profile with the SWI

In a given study year during 1996-2000, new SBC configurations were tested and statistical comparisons of SBC passage efficiency were performed, with the intent of determining the best entrance condition. Based on the collective results from the 5 years of SBC research, the best entrance configuration tested was the Single Chute, which concentrated all of the SBC flow at a single outlet (16 ft wide and 28 ft deep). Biological performance of the SBC for the Single Chute (see Table 3-6) was reported by Anglea et al. (2001), Johnson et al. (2004), and Plumb et al. (2002); no explanation was given for the discrepancy between the hydroacoustic and radio telemetry results. During the 1998 evaluation the BGS diverted 78% of the fish to the north out of the total intended for Turbine Units 1-3 behind the BGS (Adams et al. 2001). FCE of the SBC (relative to the total project) was negatively affected by spill, which passed fish before they encountered the SBC flow field. For a total powerhouse SBC, FCE is expected to be about 62% based on FCE relative to Units 4-5 (Johnson et al. 2004).

Although FCE for the SBC was not high enough for it to be a stand-alone bypass, the 1996-2000 SBC research established the potential of the SFO concept for Lower Granite Dam. It was inferred that SFO technology would likely be successful at the other dams on the lower Snake River (Little Goose, Lower Monumental, and Ice Harbor) because they are similar to Lower Granite Dam in terms of powerhouse size (6 turbine units), spillway size (8-10 spill bays), head (~100 ft), orientation (perpendicular to river flow), discharge (run-of-river), and species composition (predominately juvenile steelhead and subyearling and yearling Chinook salmon).

Table 3-6. Biological performance indices for the Lower Granite SBC

(Data are for the single chute configuration in 2000. Entrance efficiency for run-at-large and species-specific estimates was estimated for ~10 ft and ~20 ft, respectively, from the entrance.)

Species	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness
Run-at-Large Spring	0.76	0.43*	11.0
Yearling Chinook	0.84	0.29	6.7
Steelhead (wild)	0.60	0.27	6.2
Steelhead (hatchery)	0.42	0.18	3.6

* The estimate is 0.62 for spring relative to LGR Units 4-5 (Johnson et al. 2005); this represents FCE for a total powerhouse SBC.

Specific lessons learned during the SBC testing included: free-surface inflow is better than submerged flow at passing smolts; the higher the inflow and the greater the SFO flow net, the better, as shown by the relatively high performance of the Single Chute Configuration; gradual is better than abrupt water acceleration or deceleration at an SFO entrance; concentrated bulked inflow at a single entrance is better than relatively low inflow at multiple entrances; and a BGS can change the horizontal distribution of fish to the benefit of SFO performance (Johnson et al. 2005). Findings from the SBC and from other fish passage work going on in the region were applied to the design of the RSW.

The concept of an RSW was developed in a feasibility report of SFO options for Lower Granite Dam, and was selected as one of the leading options for further development and prototype application (Sverdrup and ENSR 1998a). The RSW was also one of the components considered in a systems feasibility report for the Snake River system (Sverdrup and ENSR 1998b). The early plan by the Corps was to test the concept at Ice Harbor, but because of all of the research that had taken place at Lower Granite in developing the SBC, plus the option to test the RSW in combination with other structures, including the SBC, the SWI, and the BGS, the Corps decided to do the RSW development at Lower Granite Dam instead of Ice Harbor Dam.

The Lower Granite RSW, installed in 2002, is located at Spill Bay 1, roughly in the center of the river. The single entrance is 48 ft wide and 11-16 ft deep. It is shaped with rounded side piers and a ramped approach floor, as shown in Figure 3-13. Flow into the RSW is critical, with velocity at the weir of 11-15 fps. The RSW discharges range from 5,900 to 11,500 cfs, or about 4 to 9% of total project discharge, depending on forebay elevation. Training spill is required when operating the RSW because an eddy will form in the spillway stilling basin if there is not additional spill. The RSW was initially intended to be a prototype structure for collecting fish performance information with the goal of providing important insights for future designs. However, because of the potential that the structure might eventually become part of a permanent system, it was decided to design the RSW for a longer life. Because the RSW in combination with the entire spillway needed to be able to pass the Probable Maximum Flood (PMF), "removable" capability was included in the design.

Biological performance data were collected in the 2002 RSW "Composite" test (i.e., the RSW in combination with the SBC (not operated), SWI, BGS, and log boom structures); the 2003 and 2005 RSW "Stand-Alone" tests, which included the log boom with a 4-ft underwater skirt depth; and the 2006 RSW test with and without modified BGS. The data (Table 3-7) show discovery efficiency was highest for hatchery steelhead (70%) and lowest for yearling Chinook salmon (55%). Entrance efficiency was 92% or greater, noticeably higher than the SBC (42%-84%). Over one-half of the radio-tagged spring migrants and two-thirds of the summer migrants passed over the RSW (Plumb et al. 2003, 2004). Direct survival rates were 92% or greater (Table 3-7).

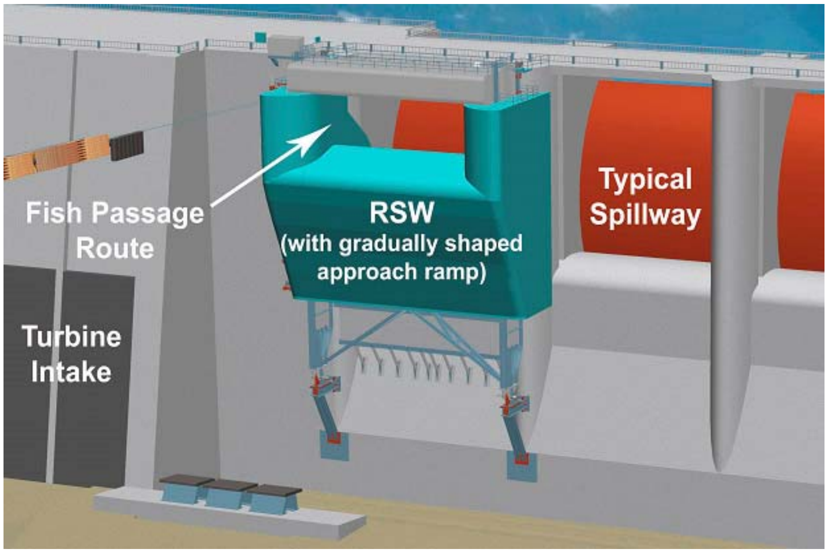


Figure 3-13. Lower Granite RSW schematic

Table 3-7. Biological performance indices for the Lower Granite RSW

(Run-at-large and species data are averages over 2002 and 2005 and 2002, 2003, 2005, and 2006, respectively.)

Species	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival
Run-at-Large Spring	---	---	0.48	9.99	---
Run-at-Large Summer	---	---	0.25	3.27	---
Subyearling Chinook	---	---	0.64	---	0.92
Yearling Chinook	0.55	0.92	0.45	7.38	0.98
Steelhead (wild)	0.68	0.92	0.59	8.33	---
Steelhead (hatchery)	0.70	0.94	0.50	8.53	0.97

Overall, the collective SFO development effort at Lower Granite Dam revealed several issues. One is that the SFO design teams need to consider the long-term biological effects to fish due to indirect mortality, injury, forebay delay and stress from passage through the SFO compared to other routes. Also, the amount of SFO inflow needed for different applications is still uncertain, and the level of gradual shaping needed for an SFO entrance (i.e., water acceleration criterion) is not yet well-defined.

On the other hand, Lower Granite SFO research produced some key findings:

- Surface-oriented, free-discharging weir-type entrances and open, natural lighting beyond the weir crest appeared to be superior at passing fish to deep-slot entrances without free-surface flow (Johnson et al. 2000).

- Gradually increasing velocity as flow approached the weir crest appeared to minimize fish passage delay or entrance rejection (Anglea et al. 2000).

- A BGS improved forebay FCE for the SBC by directing smolts toward the SFO entrance (Adams et al. 2001).
- For the retrofit SBC, it was better to concentrate inflow in one or a limited number of entrances rather than spreading the same total amount over many entrances with lesser discharges (Johnson et al. 2005).
- Spill during SBC tests showed that far-field bulk flow patterns can direct fish to other passage routes before they have an opportunity to discover SFO flow nets (Johnson et al. 2004).
- FCE for the surface spill SFO was species-dependent, with steelhead at 64-66% and yearling Chinook salmon at 57% (Plumb et al. 2004).
- The reverse curve "S" shape downstream of the RSW crest created standing waves down the chute. This condition did not appear to injure fish, but should still be minimized to avoid potential for injury.

The Lower Granite RSW is a permanent SFO that is routinely-operated during the spring and summer fish passage seasons. Future direction for SFO at Lower Granite Dam might involve adding a BGS to the RSW to gain additional in-river passage. There is also the potential for adding a powerhouse SFO structure with large-scale dewatering to enable either transport or bypass operations for juvenile salmonids. Finally, a hybrid combination of an SFO with the intake screen system might be used to pass more fish safely and economically past the project relative to what either surface spill or intake screens might do alone.

3.3.2 Little Goose

SFO development is in its early stages for the Walla Walla District's Little Goose Dam on the lower Snake River. The dam, shown in Figure 3-14, is a typical linear dam with a 130,000-cfs capacity powerhouse. Baseline biological data on fish distributions were collected in 2006. Model investigations and preliminary engineering design work are underway for an SFO. The design team is considering a surface spill SFO similar to the RSW that has an adjustable crest elevation, a so-called Adjustable Spillway Weir (ASW), which will allow biological testing with different SFO flow rates. However, the SFO design has not been finalized.

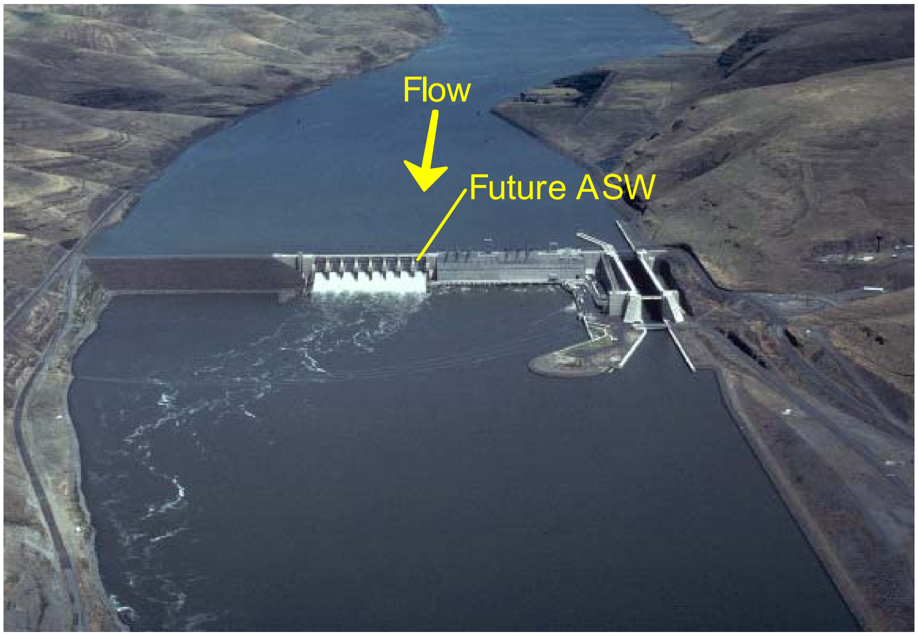


Figure 3-14. Aerial photo of Little Goose Dam

3.3.3 Lower Monumental

The Lower Monumental Hydroelectric Project, on the Snake River in Kahlotus, Washington, is a linear dam with six powerhouse units, each with a hydraulic capacity of 18,000 cfs. The dam, shown in Figure 3-15, is owned and operated by the Walla Walla District of the Corps. The successful prototype RSW that was installed at Lower Granite Dam (also a linear dam) demonstrated this type of SFO's ability to pass more fish through the project in a safer and more cost efficient manner than the existing conventional spill bays (Anglea et al. 2003; Dawson et al. 2006; Plumb et al. 2003, 2004). This success led to the development of a similar SFO design at Lower Monumental Dam. The implementation process is ongoing, with the Lower Monumental RSW under construction as of June 2007.

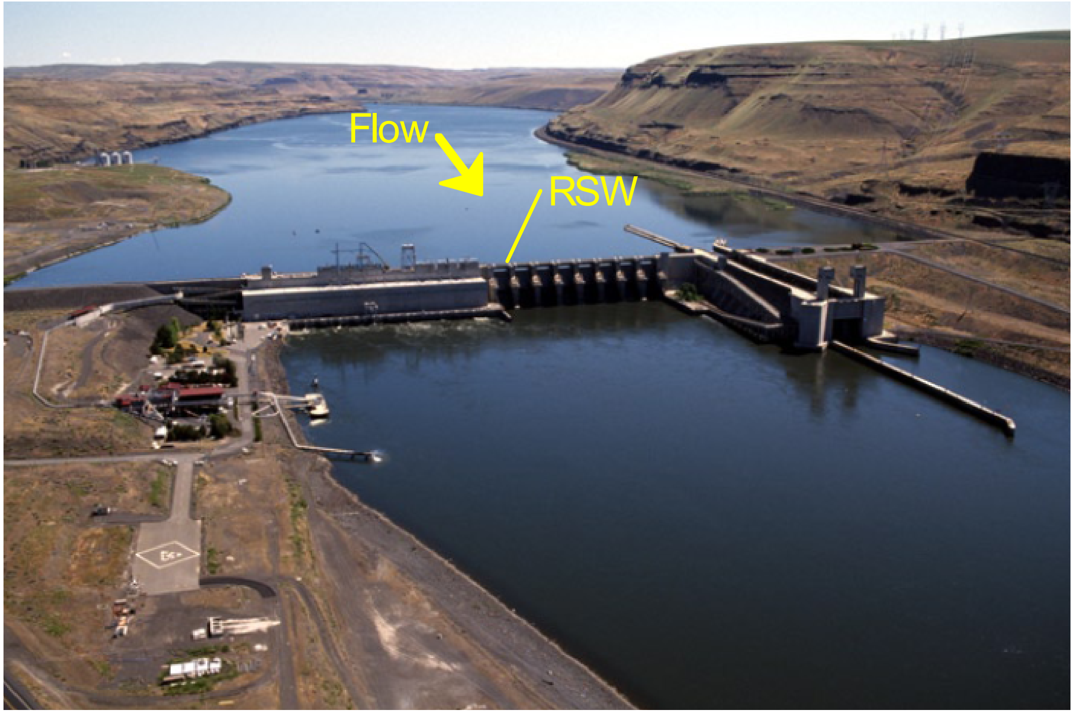


Figure 3-15. Aerial photo of Lower Monumental Dam

The Lower Monumental RSW development process began in 2005 by assessing available biological data, performing baseline telemetry data to determine forebay fish approach patterns and passage routes, and completing fish injury tests at the spillway. Then, the lessons learned from Lower Granite and Ice Harbor RSW tests were incorporated into the three potential Lower Monumental RSW designs. The final design was chosen by testing all three RSWs in a physical scale model hydraulic study (ENSR 2005). The best performing RSW in the model had, by definition, a reduced magnitude and frequency of shockwaves on the existing spillway downstream of the RSW, reduced side-wall rooster-tail shockwaves, and reduced cavitation potential at the offset transition to the spillway ogee as compared to the other potential designs. The model study results also indicated that the chosen RSW should present little risk of cavitation (ENSR 2005). The final design has a critical entrance flow regime and an entrance flow rate of 7,500 cfs (details of the hydraulic profile are presented in the next chapter in Figure 4-2).

The RSW location was selected based on biological test results and precedence from the successful Lower Granite RSW. Like Lower Granite's RSW, the Lower Monumental RSW will be located near the powerhouse. Bays 7 and 8 were initially considered. Biological tests included a 17,000- and 25,000-cfs bulk spill pattern to simulate the RSW flow in which fish survival and passage routes were monitored. These tests showed that Bay 8 had greater concentrations of fish, and less injury than in Bay 7. The greater concentration of fish is likely in the thalweg where the majority of flow approaches the powerhouse. Training spill is required with the operation of RSWs to insure that an eddy does not form in the spillway stilling basin. Bay 8 can be operated with less training spill than Bay 7 and still provide favorable tailrace conditions. For the aforementioned reasons, Bay 8 was selected as the RSW bay. A prototype RSW is currently under construction and is scheduled to be completed in 2007. Once the RSW is installed and operational, biological tests will be conducted. Adjacent spill will be optimized for both forebay attraction and tailrace egress. Other future tasks include evaluating the powerhouse unit priorities and addressing any navigational issues resulting from the installation of the RSW. The post-construction evaluation will entail several years of FCE and survival research.

3.3.4 Ice Harbor

Ice Harbor Dam is owned and operated by the Walla Walla District of the Corps. The dam, shown in Figure 3-16, is near Pasco, Washington at mile 10 on the Snake River. It has a 6-unit, 106,000-cfs powerhouse and a 10-bay spillway oriented perpendicular to river flow. The thalweg covers most of the forebay along the dam's longitudinal centerline. Original construction of Ice Harbor Dam included an ice and trash sluiceway at the powerhouse. The sluiceway served as a functional, operating SFO in the 1980s and early 1990s. However, in 1996, the sluiceway was permanently closed to accommodate a state-of-the-art turbine intake screen system as the preferred juvenile salmonid protection system at Ice Harbor Dam. Prior to the sluiceway closure, the Corps performed SFO prototype research on reconfigured sluiceway entrances at Ice Harbor in 1995 to support their Surface Bypass Program. By the 2000s, concerns about fish passage conditions in voluntary spill and performance of the screen bypass, coupled with the success of SFOs elsewhere, led managers to develop an SFO at the Ice Harbor spillway. An RSW type structure was specifically identified in the Corps' Lower Snake River Feasibility Study (USACE 2002) as a possibility for enhancing spillway passage at Ice Harbor, since this project is the only dam on the lower Snake that is a bypass-only facility (i.e., no fish transport capability). This SFO synopsis for Ice Harbor will cover research on the original sluiceway (1982-1987), the prototype reconfigured sluiceway (1995), and the surface spill RSW (2005-2006).

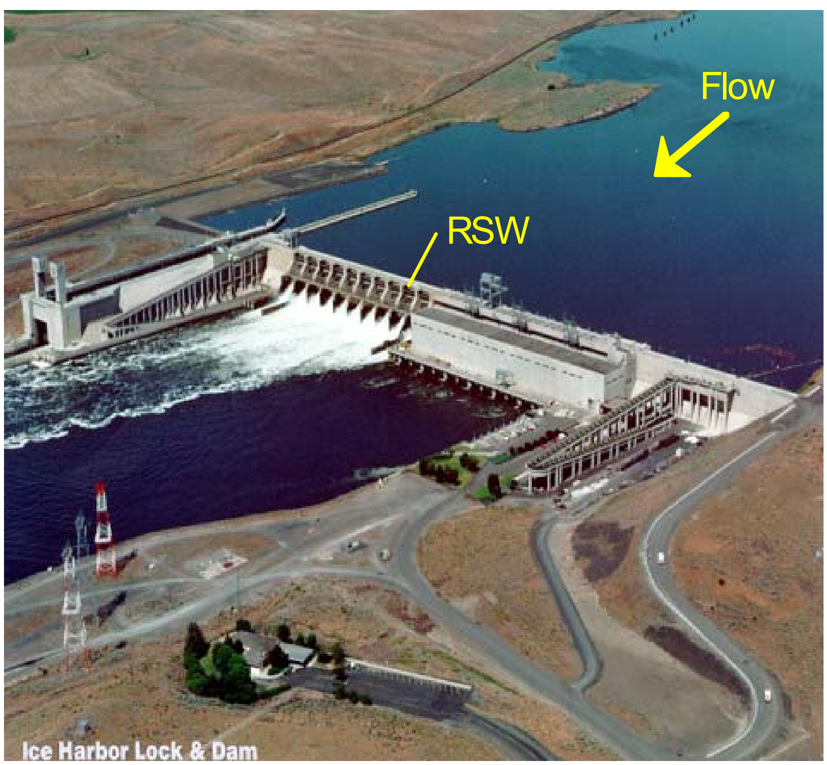


Figure 3-16. Aerial photo of Ice Harbor Dam

The original sluiceway had a critical entrance flow regime and a maximum total discharge of about 2,700 cfs through three open gates. The sluiceway channel spanned the powerhouse before emptying straight down into a conveyance channel to an outfall in the tailrace. No model work was performed on the sluiceway. Estimating FCE for various entrance conditions was a primary objective in sluiceway studies at Ice Harbor. Sluiceway FCE and FCF averaged 32% and 13%, respectively (Table 3-8). Note that the FCE data from the 1980s were collected during lower spill levels at Ice Harbor Dam than are currently prevalent.

Table 3-8. Biological performance indices for the Ice Harbor Dam sluiceway.

Species	Study-Year	Fish Collection Efficiency	Fish Collection Effectiveness
Run-at-Large Spring	1982	0.13	8.7
	1983	0.30	13.6
	1986	0.50	22.9
	1987	0.34	6.8
	mean	0.32	13.0

The 1995 research on reconfigured sluiceway entrances made use of the last year of availability of the Ice Harbor sluiceway to perform SFO development tests. The intent was to apply the results from the 1995 Ice Harbor tests to SFO development at Lower Granite Dam, where prototype tests would start in 1996. The reconfigured entrances had vertical slots that were retrofit on the dam at Turbine Intakes 1A and 4B. These SFO prototype structures deepened the area of influence of a sluice gate. In addition to operating the vertical slots, a regular, unmodified sluice gate was operated to compare to the reconfigured entrances. No modeling was done prior to the construction and installation of the reconfigured sluiceway entrance structures because of time constraints. A key result from SFO research at Ice Harbor Dam in 1995 was that an unmodified sluice entrance apparently had higher passage rates and FCEs than the sluice entrance with a reconfigured vertical slot entrance (BioSonics 1996). The SFO strategy of installing reconfigured sluiceway entrances did not enhance sluiceway performance. The biological results from the original sluiceway in the 1980s and prototype tests in 1995 were useful to the design team of the spillway weir in the 2000s, because the earlier tests showed the potential of a surface skimming SFO to pass juvenile salmonids.

The RSW at Ice Harbor Dam, which was installed in 2005, is the focus of current SFO development at the dam. The development process included baseline biological data (2002-2003), RSW engineering design and construction (2003-2004), and evaluation (2005-2006). Numerical models were used to evaluate different RSW shapes and spill bay location options prior to construction and to analyze hydraulic conditions during operational tests after construction. Physical models, one sectional and one general, were used to evaluate different design components and assess project operations (ENSR 2004). The Corps modified the previous Lower Granite RSW design for application at Ice Harbor. Design considerations for the RSW included: shaping downstream of the crest to minimize the development of standing waves; locating the entrance in an area where fish approach the project; using an open surface-oriented weir; shaping the weir to obtain gradual approach velocities; designing the SFO for long-term use with the potential to add a BGS; setting SFO flow at a high enough level (7,500 cfs) for fish to presumably discover it in the forebay, but low enough so as to not cause problems on the spillway; and providing the capacity to pass the PMF (ENSR 2004).

The Ice Harbor RSW is located at Spill Bay 2 in roughly the center of the river. The single entrance is 48 ft wide and 12-15 ft deep. It is shaped with rounded side piers and a ramped approach floor, as shown in the three-dimensional (3-D) rendering in Figure 3-17. Flow into the RSW is critical, with a velocity at the weir of 13-15 fps. The RSW discharges 7,500-10,400 cfs, or about 7-10% of total project discharge, depending on forebay elevation. Design, construction, and evaluation during 2002-2006 cost about $20M. Biological performance data for the Ice Harbor RSW were collected in 2005 and 2006. Discovery and entrance efficiency data were not reported. FCE was 28-64% and direct survival was 96-100% (Table 3-9; Axel et al. 2006). The amount of spill occurring in association with RSW operations significantly impacted FCE values.

Table 3-9. Biological performance indices for the Ice Harbor Dam RSW
(Data are averages over studies in 2005-2006.)

Species	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival
Run-at-Large Spring	0.28	---	---
Run-at-Large Summer	0.38	---	---
Subyearling Chinook	0.64	---	0.98
Yearling Chinook	0.40	5.20	0.96
Steelhead	0.42	5.30	1.00

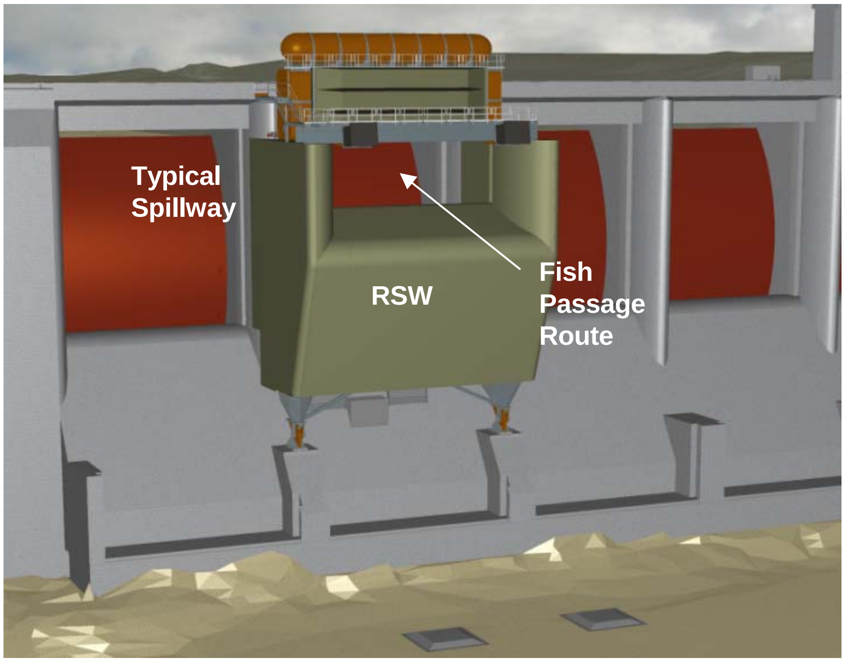


Figure 3-17. Ice Harbor Dam RSW schematic

The RSW is a long-term, permanent SFO for Ice Harbor Dam. Future enhancements may involve linking a BGS to the RSW to gain additional in-river passage with less spill and modifying the RSW spillway chute and deflector to reduce injury. The development effort for the Ice Harbor RSW produced several important key findings:

- On average, with no voluntary spill, the sluiceway passed 32% of all juvenile salmonids passing the dam during studies in the 1980s (Johnson et al. 1983; 1984; Ransom and Ouellette 1988; Sullivan et al. 1986).

- Modifying sluiceway entrances with a false front containing a vertical slot resulted in a lower FCE than was observed at an unmodified sluiceway entrance (BioSonics 1996).

- FCE for the RSW was 40-42%, using about 8% of total project discharge (Axel et al. 2006). This demonstrates the potential for a surface spill SFO at Ice Harbor Dam.

- High discharge through a deep spillway gate next to the RSW produced a competing flow for the RSW and may have reduced FCE by disrupting SFO flow-lines originating from depth (> 30 ft).
- The amount of spill in association with RSW operations will significantly impact RSW performance. For example, for the two 2006 test treatments for yearling Chinook, FCE was 51.3% and 33.1% when overall average spill was 33% and 58%, respectively.
- Based on 2005 hydroacoustic data, it appears fish guidance efficiency (FGE) for the intake screens was higher during RSW operations compared to FGE during no RSW discharge (Moursund et al. 2006).

3.4 Lower Columbia River

3.4.1 McNary

The McNary Hydroelectric Project, on the Columbia River in Umatilla, Oregon, is a typical linear configuration with a 232,000-cfs hydraulic capacity powerhouse. The dam, shown in Figure 3-18, is owned and operated by the Walla Walla District of the Corps. Based on the success of the RSWs at linear dams on the Snake River, specifically Lower Granite and Ice Harbor dams, the Corps and fisheries management agencies targeted McNary Dam for design and installation of a similar surface spill SFO option. A forebay behavior study was completed during 2006 to collect data on the fish approach and passage patterns to help locate the SFO structure(s) where fish congregate or have a high likelihood of discovery (Cash et al. In Preparation). In addition, a 1:25 scale spillway model of three spill bays (Bays 20 through 22) and one turbine unit (Unit no. 14) of McNary Dam was constructed with the primary objectives of developing a concept for prototype testing surface bypass at a spill bay in 2006 and permanently installing an SFO that may use a spill bay or the non-overflow section of the dam (ENSR 2006).

Figure 3-18. Aerial photo of McNary Dam

A temporary spillway weir (TSW) is part of an overall effort to implement SFO technology at McNary. A TSW is intended to be a fast track method of gathering information on surface passage at McNary that will help future studies and designs. Three TSWs, which utilize a weir structure upstream of the spillway gates to create a critical entrance flow top spill into a spill bay, have been tested in the 1:25 scale physical model. The critical entrance flow accelerated smoothly up and over the TSW crests (further details of the hydraulic profile are presented in the next chapter in Figure 4-2). The best performing TSW design in the model was identified based on the best nappe impact hydraulic conditions and backroller size (ENSR 2006). A smaller backroller should translate into a reduced risk for juvenile fish to become trapped in the pool and injured by the exposure to high shear forces along the boundary of the underside of the nappe and the backroller pool.

Two prototypes (TSW1 and TSW2) were installed in spring 2007 for biological evaluation. The prototype constructed TSWs have design flows of 10,000 cfs each and are two-piece structures that utilize the spill bay emergency and operating gate slots, shown in Figure 3-19. The flow nappe intersects the ogee above the tailwater elevation. Several configurations of the TSW will be tested to better understand the requirements for final installation. The biological evaluation will consist of conducting direct fish injury and survival evaluations. The biological results for TSW1 and TSW2 will be compared to each other as well as to a conventional spill bay. Pending the test results, a TSW operational plan will be developed if the biological performance is adequate. If warranted, the Corps will proceed with further development of regionally prioritized SFO alternatives at McNary Dam.

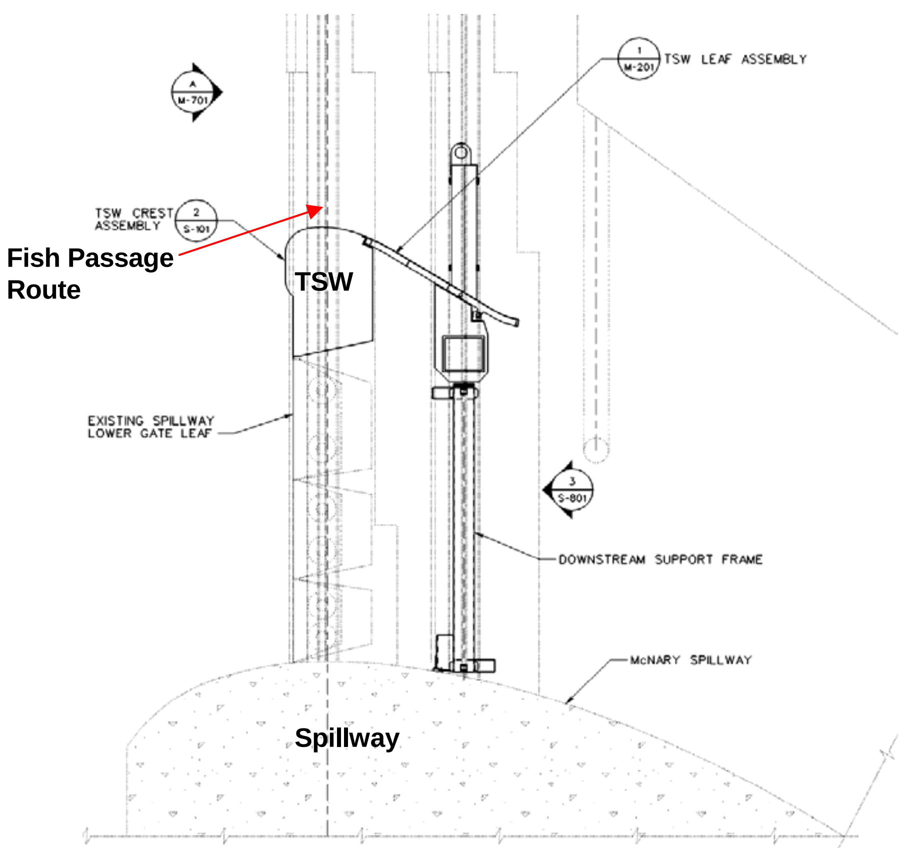


Figure 3-19. McNary TSW profile

3.4.2 John Day

John Day Dam is located on the Columbia River at River Mile 216. The dam, shown in Figure 3-20, is a linear dam with a 322,000-cfs powerhouse capacity. SFO development is in its early stages at John Day Dam. Baseline biological data on fish distributions have been summarized by Giorgi and Stevenson (1995) and Anglea et al. (2001). Generally, yearling migrants approach the dam along the Washington side of the forebay, and subyearling Chinook salmon approach using migration pathways near both shorelines. Tagged fish have been observed traversing the forebay laterally before passing. Clear cut relationships between project passage and dam operations were not apparent.

Field work on a prototype surface spill SFO was conducted in 1997 when "over/under" weirs with a critical entrance flow regime were placed at Bays 18 and 19. BioSonics (1998) found that passage at the prototype bays was higher during the spring with the weir out than in. During the summer, passage for in and out conditions were comparable. The 1997 test of the prototype surface spill SFO, however, was affected by the large amount of spill in adjacent bays during this abnormally high flow year.

Engineering and model studies examining the skeleton bays as potential SFO sites were conducted in the 1990s (Montgomery Watson 1998). At a physical model at ERDC, observations of a 20,000-cfs SFO in a skeleton bay showed strong forebay flow nets, indicating a potential for fish to discover the SFO flow. However, because of concerns about cost and tailrace egress caused by a large eddy that formed in the spillway stilling basin adjacent to the SFO outfall plume, this effort was tabled.

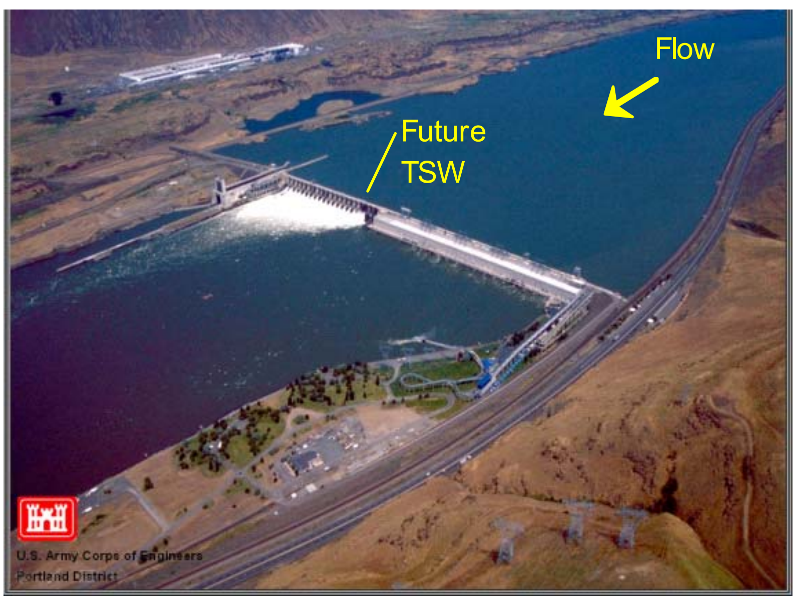


Figure 3-20. Aerial photo of John Day Dam

Currently, new model investigations (CFD and general physical scale) and engineering design work are underway to develop a prototype SFO for John Day Dam. In 2008, the Portland District plans to install a prototype surface spill SFO, called a Top Spill Weir, in two spill bays near the powerhouse. The device will rest on spillway stop logs. A bulkhead on top of the weir will provide hydraulic control, creating a critical entrance flow regime. The anticipated discharge is about 10,000 cfs per bay. The weir is being designed to minimize the angle of SFO jet impact on the ogee. Results from the injury and survival tests in 2007 at the McNary TSW will be applied to the weir design for John Day Dam. The 2008 evaluation of the John Day Top Spill Weir will examine whether the prototype SFO moves fish away from the powerhouse, thereby decreasing turbine passage. Current SFO work at John Day Dam is part of the project's Configuration Alternatives Evaluation Study.

3.4.3 The Dalles

The Dalles Dam, owned and operated by the Portland District of the Corps, located at mile 192 on the Columbia River, has a Z-configuration with a spillway perpendicular to the main river channel, a powerhouse parallel to the main river channel, and non-overflow dams on each side of the powerhouse, as shown in Figure 3-21. A key feature of the 270,000-cfs powerhouse is an ice and trash sluiceway that spans its entire length, with leaf gates above each turbine intake. The thalweg intersects the dam at the eastern end of the powerhouse, and although there are deep areas immediately in front of the powerhouse, much of the forebay is relatively shallow (< 65 ft deep). Voluntary spill of 40% total discharge is presently the main strategy to protect juvenile outmigrants. Since the 1980s, the sluiceway has been recognized as a relatively efficient, useful non-turbine passage route for juvenile salmonids, and over the years has been the object of SFO development efforts at The Dalles Dam. SFO alternatives studies were conducted by Harza and ENSR (1996) and Harza et al. (1995). Prototype and model studies for SFO-related structures at The Dalles Dam provide useful lessons in SFO development.

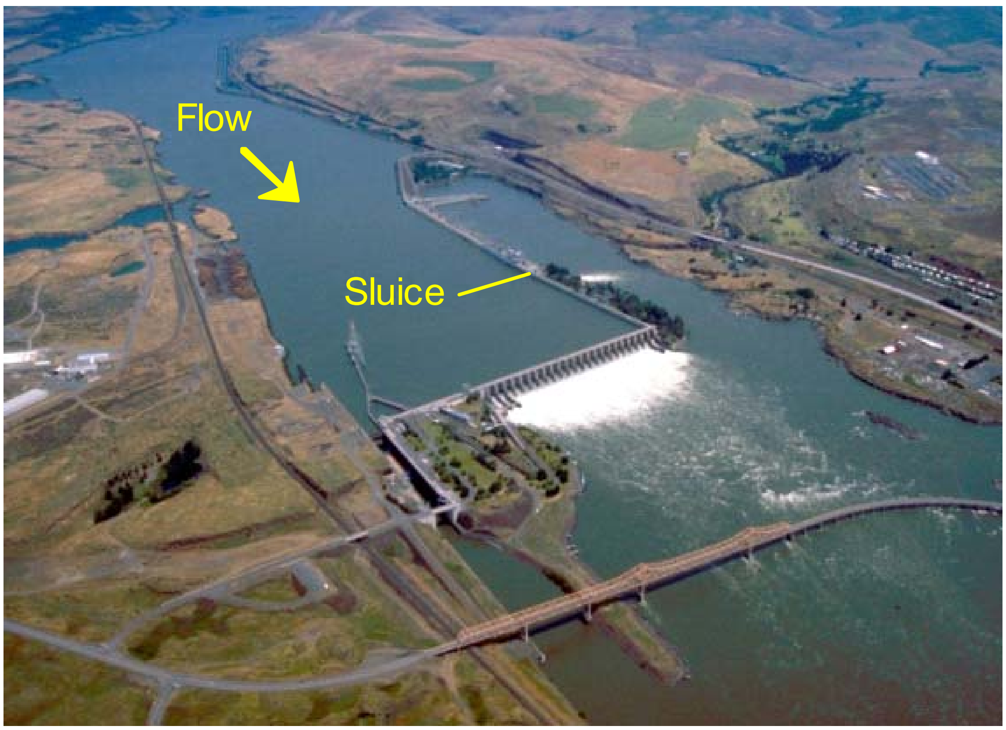


Figure 3-21. Aerial photo of The Dalles Dam

During the initial phase of the Corps' Surface Bypass Program in the mid-1990s, SFO development at The Dalles Dam was a top priority. The program commenced in 1994, and by the spring of 1995 prototype SFO structures had been designed, constructed, and installed at the spillway and sluiceway. The spillway had a prototype top spill surface weir at Bay 6 and vertical slot baffles at Bay 12, each with critical entrance flow regimes. The 3,200-cfs discharge at the prototype SFO spill bays was limited by structural constraints of the baffles and weirs; thus, SFO discharge was dwarfed by 14,500 cfs in adjacent bays. Researchers did not report fish passage data from the spill bay SFO prototype tests because the study was compromised by large flow differences between test and control bays (Nagy and Shutters 1995). Over at the sluiceway, the Corps deployed two reconfigured entrances with turbine intake occlusion, called "surface skimmer" vertical slots. They were basically hollow boxes that covered the upper 30 ft of the turbine intake, opened to the sluice sill entrance on the backside, and allowed flow from the forebay through two vertical slots, one per intake, on the front side. Flow was not ramped or shaped, and hydraulic conditions inside the prototype SFO were turbulent. Biological studies indicated passage rates at the prototype surface skimmer were less than those at an unmodified sluiceway entrance (Nagy and Shutters 1995). The vertical slot prototype SFOs at the spillway and sluiceway were abandoned by 1997 because of limited discharge capability and unacceptably low fish passage rates, respectively, resulting in part in other dams replacing The Dalles Dam as a priority for SFO development.

Turbine intake occlusions with “J-blocks” were deployed and evaluated during 2000-2002, as shown in Figure 3-22. We include the J-blocks in this SFO Compendium because, although the primary intention was to reduce turbine passage rates, a secondary objective was to enhance sluiceway passage. The concept underlying J-blocks, and turbine intake occlusion in general, is to deepen the source for water from the forebay that feeds the turbines, so surface-oriented juvenile salmonids are less likely to be entrained in turbine flow. In addition, the upstream extension of the J would provide a low velocity area adjacent to the power intakes where fish may move laterally before encountering sluiceway flow. For the prototype J-block tests at The Dalles Dam, the upper half (50 ft) of the intakes at Main Units 1-5 was occluded. Approximately 3,600 cfs flowed into the sluiceway above the occlusions, while 67,500 cfs flowed into the turbine units below. Flow characteristics with the J-blocks were examined in a 1:25 scale sectional model before construction and in a CFD model afterward (Johnson et al. 2003).

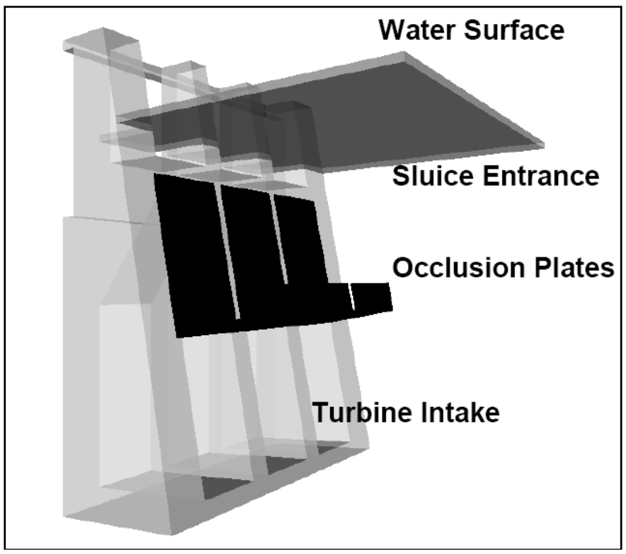


Figure 3-22. The Dalles Dam occlusion plates (J-blocks)

During the most comprehensive study of J-occlusions (2002), the results did not indicate a clear, definite advantage of deploying intake occlusion plates for the purpose of smolt protection at The Dalles Dam. During spring, both the hydroacoustic and radio-telemetry data usually showed no significant differences between IN/OUT treatments for various response variables. During summer, the hydroacoustic study showed negative effects in terms of MU 1-4 turbine passage during day and night (Johnson et al. 2003). On the other hand, the radio telemetry study demonstrated positive effects in terms of sluiceway efficiency during night, but all other statistical comparisons were insignificant (P>0.05; Hausmann et al. 2004). The CFD data indicated that the water current patterns in the forebay were stronger downward toward the turbines with the J-occlusions IN than OUT (Johnson et al. 2003). Block loading MU 1-5 during the 2002 J-occlusion evaluation affected forebay flow patterns by creating a strong current toward the west end of the powerhouse.

Another supplemental SFO device for The Dalles Dam, a forebay BGS, underwent modeling and engineering design during 2005-2006 (USACE 2006). When coupled with an SFO, a BGS is intended to improve discovery efficiency by diverting fish horizontally in a forebay toward an SFO flow net. The purpose of The Dalles Dam BGS, however, was simply to decrease turbine passage by diverting juvenile salmonids to the spillway. The recommended design was a tethered concept where a floating wall is anchored to the river bottom (USACE 2006). This design appeared to be very "flow-friendly" in model studies; however, this particular design, location, and orientation would have created unsatisfactory flow conditions in the forebay with respect to navigation. Any future BGS designs for The Dalles Dam forebay will address this concern.

The production SFO at The Dalles Dam is the ice and trash sluiceway at the powerhouse. Water enters the sluiceway channel from the forebay when gates are moved off the sill at elevation 151 ft. A maximum of six sluice gates can be opened at any time before reaching the hydraulic capacity of the channel (~4,500 cfs). Flow into the sluiceway is dependent on forebay elevation and the number and location of open gates. Initial research established that downstream migrants used the sluiceway and led to a recommendation of "full-time operation of the ice-trash sluiceway at The Dalles Dam with maximum flow" (Michimoto 1971). In 2004 and 2005, the Corps maximized flow through the sluiceway and did research to identify sluiceway entrances to open, seasonal differences, and operating turbines (e.g., Johnson et al. 2005; 2006). The sluiceway passes about 1/10th of total project passage during the 40% spill operation; relative to the powerhouse, the sluiceway passes 30-55% of total powerhouse fish passage in spring and 5-30% in summer (Johnson et al. 2007). FCE ranged from 6-14% (Table 3-10); these values were negatively affected by the 40% spill operation at The Dalles Dam.

Table 3-10. Biological performance indices for The Dalles Dam sluiceway

(Run-at-large data are from 1999-2002, 2004, 2005. Species data are from 2002-2005.)

Species	Fish Collection Efficiency	Fish Collection Effectiveness
Run-at-Large Spring	0.14	6.8
Run-at-Large Summer	0.08	4.5
Subyearling Chinook	0.06	2.5
Yearling Chinook	0.11	4.4
Steelhead	0.10	5.9

Paired-release recapture survival estimates from the top of the sluice channel to 1,640 ft below the spillway was 0.97 for yearling Chinook salmon and 0.86 for subyearling Chinook salmon, as averaged over studies in 2002 (Counihan et al. 2006a), 2004 (Counihan et al. 2006b), and 2005 (Beeman et al. 2006). Other biological performance indices at The Dalles sluiceway are shown in Table 3-10. Preliminary data on sockeye salmon passage were collected in 2004 (Cash et al. 2005); however, we did not include these data because the sample size was relatively small (n=75).

While the sluiceway continues to be operated routinely to pass juvenile salmonids, an engineering design initiative for sluiceway enhancements is being considered as part of the Corps' Surface Bypass Program. This work may utilize a previous design effort to relocate the sluiceway outfall that is currently on hold, pending regional discussions. Other sluiceway enhancements may entail modifications to achieve flow shaping.

Key findings from SFO development at The Dalles Dam are:

- The sluiceway passed a significant percentage (6%-14%) of the juvenile salmonids that were passing the entire project for the ~2.5% amount of water it used (Beeman et al. 2001).
- As was observed at Ice Harbor Dam, modifying sluiceway entrances with a false front containing a vertical slot resulted in lower FCE than was observed at an unmodified sluiceway entrance (Nagy and Shutters 1995).

- FCE for the sluiceway is dramatically affected by competing flows at the spillway (40% spill operations). As an example, for FCE relative to the powerhouse, sluiceway FCE during tests in 2005 was 33% in spring and 22% in summer (Johnson et al. 2005).

- Turbine intake occlusion did not appear to substantively enhance sluiceway passage (Johnson et al. 2007).

3.4.4 Bonneville First Powerhouse

The Bonneville First Powerhouse (B1), owned and operated by the Portland District of the Corps, the second oldest on the Columbia River after Rock Island, is oriented perpendicular to flow, as shown in Figure 3-23. It has 10 turbine units with a hydraulic capacity of 136,000 cfs. The forebay is relatively shallow (mean depth ~55 ft), as are the turbine intake ceilings (~6 ft below the surface). B1 is part of the Bonneville Dam complex that includes a navigation lock, spillway, and a second powerhouse. Original construction for B1 included a sluiceway to pass ice and trash. However, since the 1970s, the sluiceway has been opened annually to pass juvenile salmonids around turbines (Willis and Uremovich 1982). In 1996, turbine intake occlusion was tested as a means to enhance sluiceway passage. Finally, based on positive performance of the sluiceway (Table 3-11), poor performance of an intake screen bypass system, and the advent of the Corps' Surface Bypass Program, a prototype SFO called the Prototype Surface Collector (PSC) was installed and evaluated from 1998 to 2000.

Figure 3-23. Aerial photo of Bonneville Dam showing First Powerhouse (B1)

Table 3-11. B1 Sluiceway fish collection efficiency

(FCE data are averaged over 2000-2002, 2004, 2005. Survival data are averaged over 2004 and 2005.)

Species	Fish Collection Efficiency	Fish Collection Effectiveness	Total Survival Rate
Subyearling Chinook	0.58	15.85	---
Yearling Chinook	0.49	16.60	---
Steelhead	0.55	24.60	0.96
Run-at-Large Spring	0.34	9.74	---
Run-at-Large Summer	0.46	5.44	---

In 1996, trashracks at Units 3 and 5 of B1 were blocked to Elevation 33 ft (about 41 ft deep) as an inexpensive, preliminary surface bypass test. The purpose of the blockages was to occlude part of the intake entrance area to intensify and deepen the "zone of separation" between the turbine flow and surface sluiceway flow. The hypothesis was that smolts would avoid a region of rapidly changing flow characteristics, stay surface-oriented, and thereby pass into the sluiceway. Blocking in spring increased sluiceway passage at Gate 3B by 14.6% and at Gate 5B by 12.8%; however, neither increase was statistically significant because the tests lacked sufficient statistical power (Ploskey et al. 1998b). In the summer of 1996, blocking did not significantly increase sluice passage or sluice passage efficiency (Ploskey et al. 1998b). Thus, the results were inconsequential.

An extensive effort to identify SFO design alternatives for B1 was undertaken in the mid-1990s (Harza and ENSR 1996). The three finalists for a powerhouse SFO were: Alternative A with collection along the entire face of B1; Alternative B with a high flow corner collector at the south end of B1; and Alternative C with a bypass channel attached to turbine intakes containing extended bar screens. Based on a comparative analysis and ranking of the concepts by Harza and ENSR (1996) only Alternative A was selected for prototype evaluation. To test the SFO entrance concept for Alternative A, the PSC was retrofit to the upstream face of B1 at Units 3-6 in 1998 and extended to Units 1-6 in 2000 (Johnson and Carlson 2001). The purpose of the B1 PSC (Figure 3-24) was to provide a field site to investigate hydraulic and biological performance for a potential surface bypass at B1. Fish entering the PSC passed through the structure into the turbine intake behind the PSC. The PSC was not designed to actually bypass fish around turbines. The intent was to use the PSC to examine entrance hydraulics and to examine the efficacy of SFO technology at B1 before building a large-scale prototype or full production version.

Throughout the Corps' Surface Bypass Program, physical models have been used to investigate specific design elements in the development process. PSC alternative A was modeled in the 1:40 scale physical model of B1. Design elements of the PSC were investigated on the B1 1:25 scale sectional and 1:40 scale general models. A CFD model was used to examine the velocity regimes approaching, passing under, and entering the PSC. Also, hydraulic data for the B1 PSC were derived from a 1:25 sectional model, and are presented in Table 3-12. The B1 PSC extended across the face of Units 1-6. Each unit discharged 10,000 cfs. The "vertical slot" entrances were 5 to 20 ft wide, depending on configuration, and 44.5 ft deep. Both of the tested entrance flow widths created a subcritical entrance flow regime. They were located in the center at each unit for a total of six entrances.

Extensive biological evaluations of the B1 PSC were undertaken during a 3-year test period, 1998-2000. The data indicated that the SFO technology collected smolts and minimized turbine passage at B1, with FCEs at 43% and 45% for yearling Chinook salmon and steelhead, respectively (see Table 3-13). FCE was similar between spring and summer (i.e., it did not decrease in summer, as is the case with other smolt bypass approaches). According to radio telemetry data from 2000, had the PSC been a functional bypass system, it would have increased fish passage efficiency at Bonneville Dam 18% for steelhead and 10% for yearling

Chinook salmon. Projecting the PSC to cover the entire B1 powerhouse, FCE estimates are 83% and 84% for spring and summer, respectively (Ploskey et al. 2000). FCF ranged from 2.2-2.9 (Table 3-13). In the end, a full powerhouse SFO as prototyped by the B1 PSC was discarded as a design alternative because of uncertainty about fish response to forebay flow fields from a ramped entrance structure, the complexity of the conveyance and outfall structures, and the projected cost of about $200M. Currently, B2 is the priority powerhouse at Bonneville Dam.

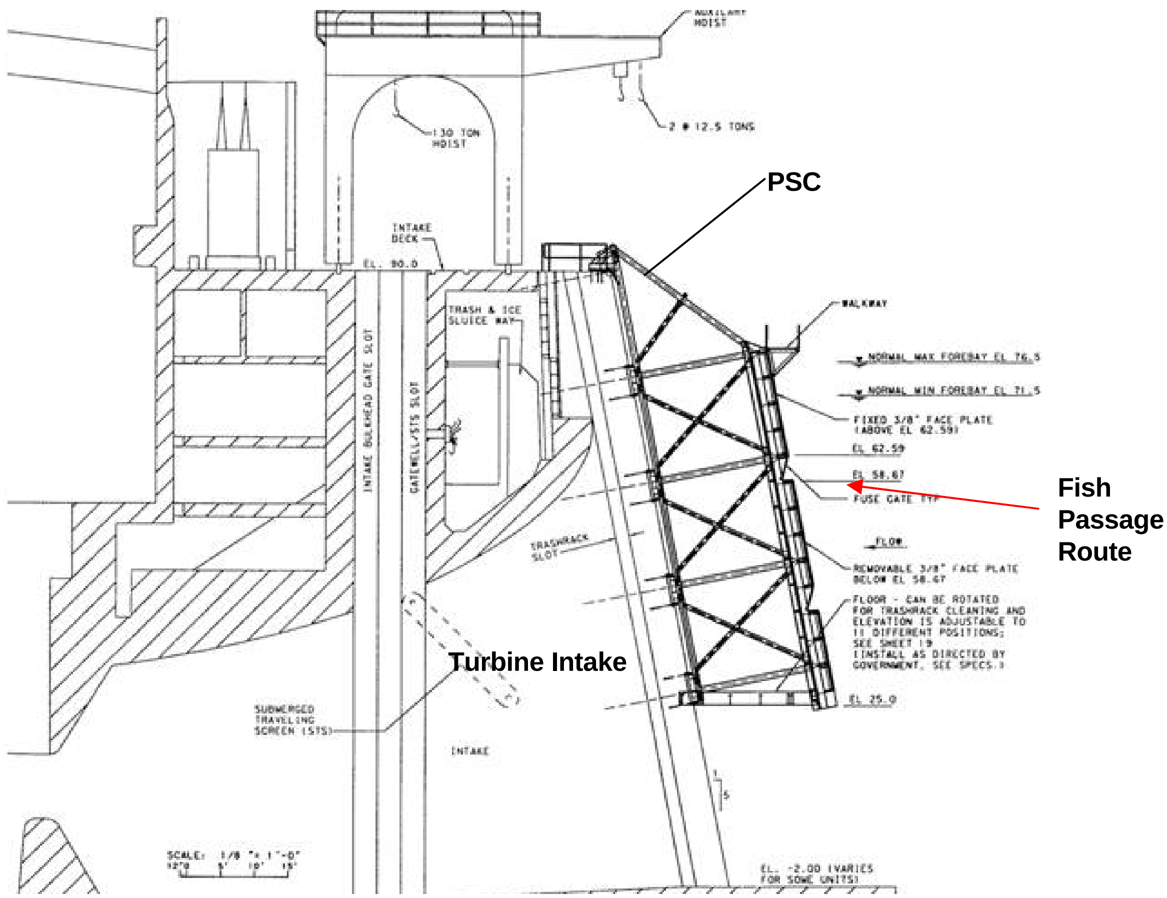


Figure 3-24. Bonneville First Powerhouse PSC profile

Table 3-12. Hydraulic parameters at B1 PSC entrance

Parameter	5-ft	20-ft
Flow (cfs)	1,700	3,300
Entrance Velocity (fps)	7.1-8.3	3.8-4.6
Area (ft^2)	223	890

Although the B1 PSC has been removed from the dam, the sluiceway continues to be a valued passage route for juvenile salmonids at Bonneville Dam. It may provide the basis for developing a more extensive SFO at B1 in the future because of its relatively high FCE (~0.50) and effectiveness (>15; Harza et al. 2001). Sluiceway improvements are underway to remove the juvenile bypass system wall that is not necessary anymore because the intake screens have been discarded. This will increase sluiceway discharge. Also, the Corps is installing automated gates to follow forebay elevation. There are also options being discussed for a partial powerhouse retrofit SFO or a B1 corner collector with BGS, both entailing new conveyance and outfall structures.

Table 3-13. Biological performance indices for B1 PSC

(Indices were determined from 2000 data. DE is based on fish detected anywhere in the B1 forebay. EE is based on detection range of radio telemetry antennas on the face of the PSC; assumed to have a 20-ft range.)

Species	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness
Yearling Chinook	0.63	0.72	0.43	2.2
Steelhead	0.74	0.60	0.45	2.3
Run-at-Large Spring	---	---	0.58*	2.9
Run-at-Large Summer	---	---	0.57*	2.9

* Relative to B1 Units 1-6, the FCE estimates are 0.83 and 0.84 for spring and summer, respectively. These estimates represent FCE for a total powerhouse retrofit SFO at B1.

Key findings from SFO development at B1 include:

- The B1 sluiceway is an efficient and effective SFO, with overall mean FCE of 48% and FCF of 15 (Appendix B; Willis and Uremovich 1982; Ploskey et al. 2006; Regan et al. 2006). The B1 sluiceway is successful because it is located where juvenile salmonids congregate.

- Trash rack occlusion to increase sluiceway passage was not promising (Johnson and Giorgi 1999).

- The PSC studies demonstrated a full powerhouse retrofit SFO at B1 has the potential to produce an FCE of greater than 80% (Ploskey et al. 2000). Multiple wide, deep entrances with 3,300-cfs inflow each passed appreciable numbers of fish.

3.4.5 Bonneville Second Powerhouse

The Bonneville Second Powerhouse (B2), which began operation in 1982 with a state-of-the-art juvenile bypass system using turbine intake screens, was built with an ice and trash sluice chute that was modified into a fully functional, permanent SFO in 2004. The ice and trash chute outlet is on the left side (looking downstream) of a powerhouse with a hydraulic capacity of 152,000 cfs. B2 has eight main turbine units and two fish units. The powerhouse is generally perpendicular to flow in the forebay, a key feature of which is a large, clockwise eddy that forms in the left half of the forebay under most project operating conditions, as shown in Figure 3-25. In the early years of B2 operation, biologists observed concentrations of smolts in this eddy and in flow entering the ice and trash chute whenever it was opened (Magne 1987). Forebay bathymetry, which is the result of excavation, has a shallow sill (40-50 ft deep) until it slopes and deepens to 100 ft within about 200 ft of the powerhouse. With less than satisfactory performance of the intake screen juvenile fish bypass system (e.g., fish guidance efficiency for subyearling Chinook salmon at B2 was assumed to be 18% for the purpose of modeling exercise (Ferguson et al. 2005)) and the initiation of the Corps' Surface Bypass Program, the SFO design team turned to the B2 ice and trash sluice chute as a basis for increasing project passage survival for juvenile salmonids at B2, while the intake bypass continued to operate.

Although baseline biological data were collected in 1996 and 1997, the turning point in B2 SFO development came with the 1998 study (Johnson and Giorgi 1999). Researchers using radio telemetry techniques estimated that FCE for the ice and trash chute was 36-52%, depending on species (Hansel et al. 1998). Given the encouraging results of the 1998 biological studies, fisheries managers and the Corps committed to development of the B2 SFO, called the B2 Corner Collector (B2CC). This development would entail a new entrance gate, ogee, conveyance channel, and outfall that would increase SFO discharge from 3,000 to 5,300 cfs and transport fish safely past the B2 powerhouse to a release location 0.5 miles downstream at a specially-designed outfall (USACE 2002).

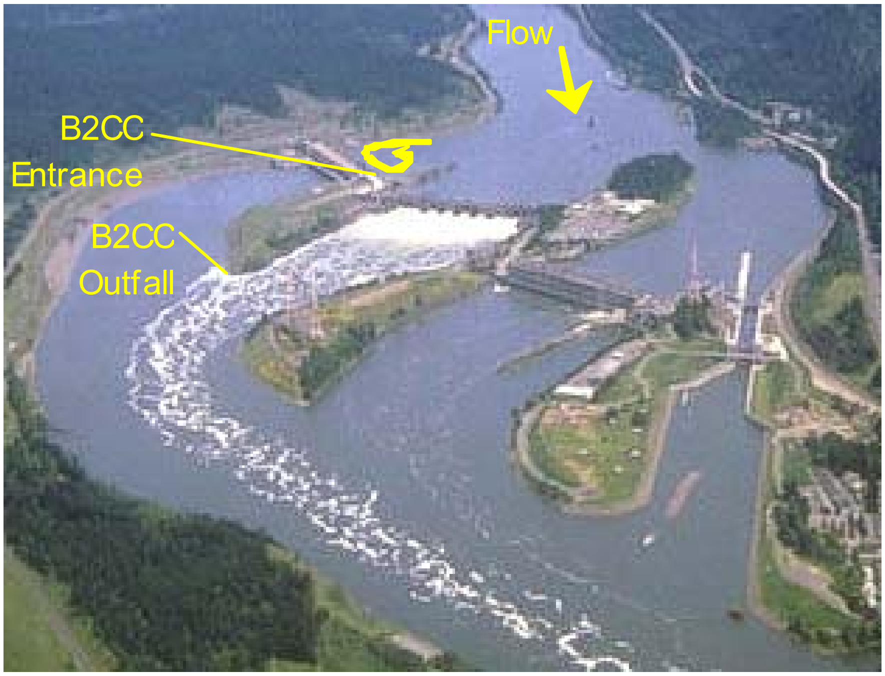


Figure 3-25. Aerial photo of Bonneville (B2) Dam

Numerous physical scale and CFD model studies were conducted to support development of the B2 Corner Collector SFO. A general physical model of Bonneville Dam (1:100 scale) was used to examine forebay and tailrace hydraulic conditions. Entrance shapes, floor elevations, modifications to the dam face, the ogee, and powerhouse operations were studied in a 1:40 scale forebay physical model (BioAnalysts et al. 2001). CFD modeling of the tailrace and the entrance/ogee was used in consort with physical modeling for alternatives investigation as well as final design (Rakowski et al. 2001). In addition, a study of forebay characteristics at the entrance to the B2 Corner Collector for optimizing powerhouse operations employed the CFD model.

During development of the B2 Corner Collector, the most pressing issue concerned the outfall. The old ice and trash chute outfall emptied into the tailrace just below the powerhouse, an area known from previous research to have the potential to harbor piscivorous fishes. The new outfall would to be located and designed to provide safe entry into the tailrace and safe egress downstream. Existing outfall guidelines (e.g., 25 fps entry velocity), however, were not applicable to a high flow (> 1,000 cfs) outfall; therefore, research was conducted to examine fish injury and survival rates for the B2 Corner Collector outfall in particular and high flow SFO outfalls in general (PNNL et al. 2001). Direct injury and mortality data indicated that a jet entry velocity of 50 fps or less should safely pass juvenile salmonids at high-flow outfalls (Johnson et al. 2003). Guidelines to design and locate high flow outfalls from the high-flow research, coupled with extensive modeling and engineering for the B2 Corner Collector outfall, led to a mid-level cantilever design with a 50-ft-deep plunge pool located off the tip of Cascades Island (USACE 2002).

The production SFO for B2 has one entrance (15 ft wide and 23 ft deep), as shown in Figure 3-26. Critical flow of about 5,300 cfs enters the outlet; this is 3.5% of the B2 powerhouse hydraulic capacity. There is no special entrance shaping, although it is important to note that the existing ice and trash chute is oriented 45˚ off the face of the powerhouse in a corner with a large forebay eddy. The ogee provides a smooth transition for the 23-ft drop and 45˚ turn downstream of the entrance weir. An open, rectangular channel 15 ft wide carries the supercritical flow along Cascades Island 0.5 miles to the outfall.

Biological performance for post-construction evaluations in 2004 and 2005 (expressed as arithmetic means) show that the B2 Corner Collector collects over 1/3 of all Chinook salmon and over 2/3 of all steelhead trout passing B2, with FCF greater than 5.8 and essentially no mortality (Counihan et al. 2006; Ploskey et al. 2006; Regan et al. 2006; Table 3-14).

Table 3-14. Biological performance indices for the B2 corner collector

(Data are averages over studies in 2004-2005.)

Species	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate
Subyearling Chinook	0.39	5.8	1.015
Yearling Chinook	0.33	6.5	1.020
Steelhead	0.70	13.7	1.010
Run-at-Large Spring	0.32	5.8	---
Run-at-Large Summer	0.42	7.5	---

The B2 Corner Collector is operated routinely from April through August each year. Possibilities for future improvements include entrance and/or forebay guidance structures to increase FCE for yearling and subyearling Chinook salmon. Key findings and lessons learned include:

- The shallow forebay sill compresses fish toward the surface, where they are available for surface passage.
- The strong lateral current across the dam carries fish toward the corner collector, and the eddy in the vicinity of the B2CC re-exposes smolts to that SFO route.
- Collectively, the water current characteristics and shallow forebay make this an efficient SFO (FCE = 32-72%, depending on species) by maximizing discovery efficiency.
- High entrance flow (5,300 cfs) and a large cross-sectional area (15 ft wide and 23 ft deep) contributed to high FCE.
- Outfall jet entry velocities up to 50 fps are safe for fish (Johnson et al. 2003).
- The specially-designed conveyance structure and outfall provides a benign passage route with a direct survival rate of 100% (Counihan et al. 2006).

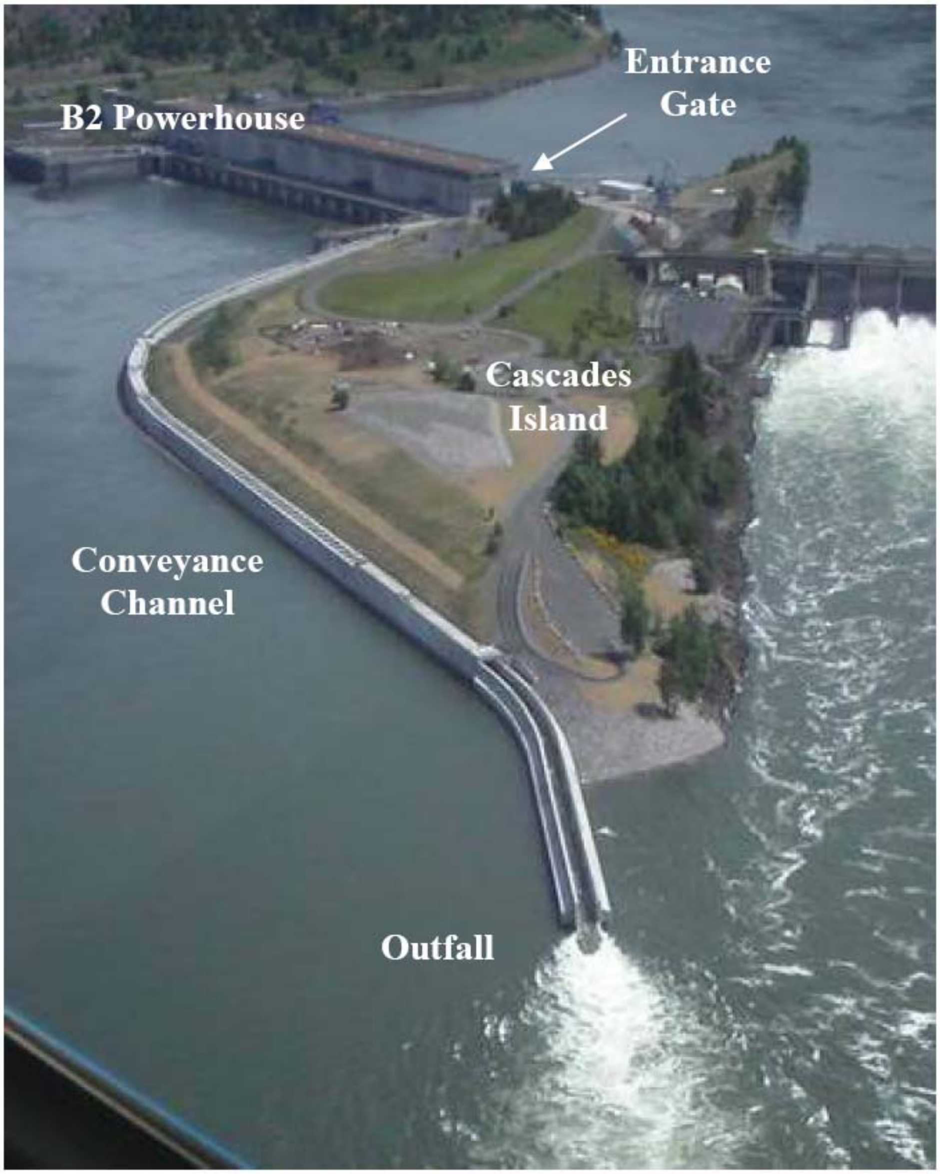


Figure 3-26. B2 SFO layout: corner collector entrance, conveyance channel, and outfall

3.5 Other Pacific Northwest Rivers

3.5.1 Mayfield

The Mayfield Hydroelectric Project, located on the Cowlitz River near Mayfield, Washington, is a linear dam with a 13,660-cfs hydraulic capacity powerhouse. The dam, shown in Figure 3-27, is owned and operated by Tacoma Power. An SFO facility (Figure 3-28), which has been operational at Mayfield Dam since 1963, consists of a forebay surface collector with a louver guidance system. The guidance system is comprised of two large V-shaped vertical louvered subcritical flow entrances that guide fish to a bypass slot that is 8 inches wide. From the bypass slot fish are guided into a bypass pipe and delivered to a secondary dewatering unit (separator). The fish are then transported downstream of the dam to a collection facility or directed into a transport pipeline that discharges at an outfall in the powerhouse tailrace.

Several biological studies were performed during the first few years of the SFO operation (Smith et al. 1968; Thompson and Paulik 1967). During 1964 and 1965, gill nets and a trawl were systematically sampled to determine the horizontal and vertical distributions of juvenile salmonids. The intent of the study was to provide data for design of potential fish collection facilities in such an environment. Eighty-seven percent of the juvenile salmonids captured during the study were taken in the upper 24 ft of the water column, supporting the SFO premise that the majority of juvenile salmonids at that site are surface-oriented. Also during this time, juvenile coho, Chinook, steelhead, and cutthroat were marked then released in Mayfield reservoir and recaptured in the SFO bypass sampler (guided) and in special louver systems (unguided) to determine the fish guidance efficiencies. In general, the louvers seemed to effectively guide fish, toward the bypass entrance. However, the bypasses entrances were determined to be too narrow for yearling fish and the hydraulics at the bypass entrance were not conducive to fish passage. Past estimates of FCE from the 1960's suggest that nearly 60-80% of the migrant fish are collected by the louver guidance system (Table 3-15). Mean estimates of FCE from two years of study (1964, 1965) showed that steelhead had the highest collection efficiency at 77%, followed by Chinook at 75% and coho at 56% (Thompson and Paulik 1967).

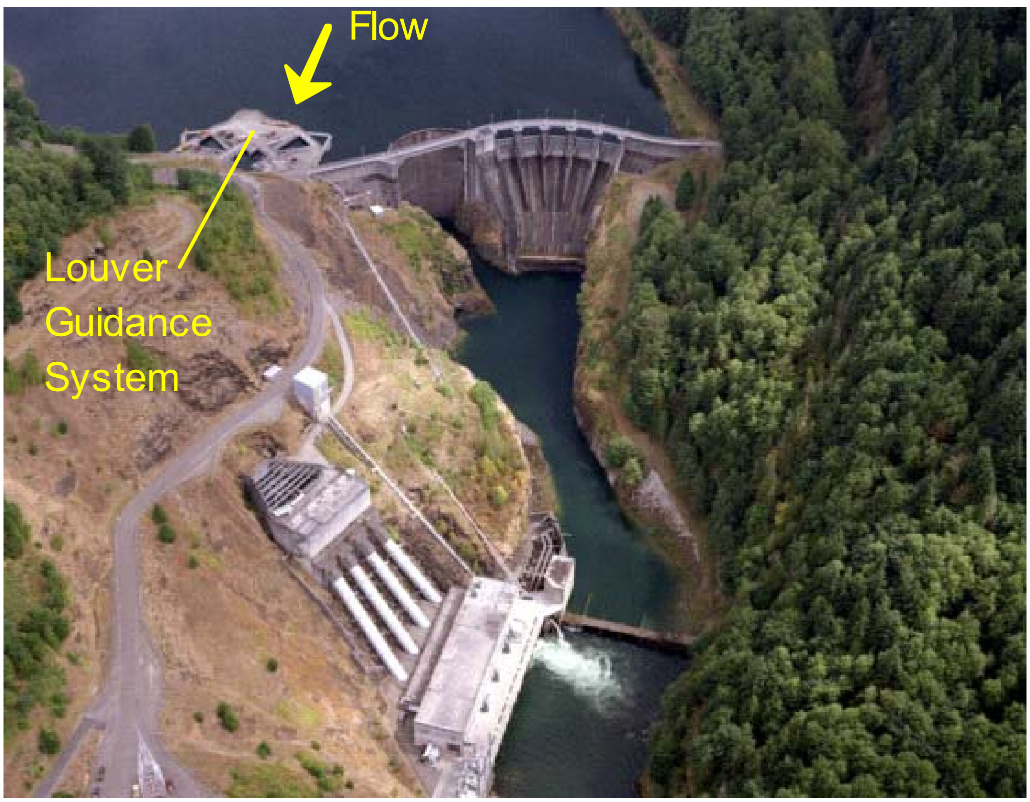


Figure 3-27. Aerial photo of Mayfield Dam

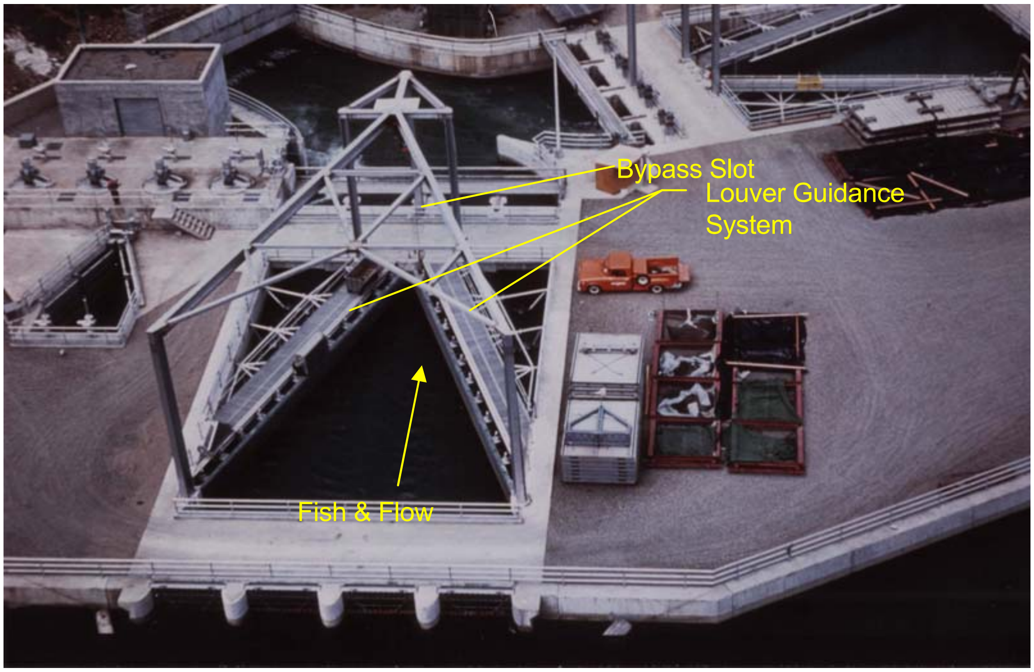


Figure 3-28. Aerial view of Mayfield louver and SFO system

In accordance with FERC's relicensing of the Cowlitz Hydroelectric Project in the 1990's, the existing louver guidance system was evaluated by performing and comparing biological results and CFD modeling data. In 2001, a CFD study of the louver bays was completed in conjunction with an acoustic tag study, which tracked juvenile coho movements through the louver system. Fish behavior was then compared to the hydraulic conditions calculated by the CFD model. It was determined that some areas within the intake exhibited poor biological performance. Fish swam back and forth through the louver vanes, and many fish approached the bypass entrance and then rejected it. Minor facility upgrades were recommended to improve the biological performance, such as implementing visual cues for the fish or further investigating minor structural changes to the entrance slot and louver panels with additional CFD modeling. A recent estimate (2001) showed that the Mayfield SFO had a FCE of 67% for coho salmon (Table 3-15; Zapel et al. 2002). No estimates of discovery efficiency, entrance efficiency or survival have been reported for the louver guidance bypass system at Mayfield Dam.

Table 3-15. Biological performance indices for the Mayfield Dam louver guidance system

(FCE estimates are averaged over 1964, 1965, and 2001.)

Species	Fish Collection Efficiency
Steelhead	0.76
Yearling Chinook	0.75
Coho	0.60

In 2006, additional CFD modeling work was done to further characterize the louver and bypass entrance hydraulics, although more hydraulic analyses are warranted. Future work will likely include performing a debris management study, analyzing the louver bay hydraulics and secondary separator screen and baffles, remodeling the counting house, and upgrading the discharge chute.

3.5.2 Cowlitz Falls

The Cowlitz Falls Hydroelectric Project, owned and operated by Lewis County PUD, shown in Figure 3-29, is a hydrocombine dam with a powerhouse capacity of 5,250 cfs located on the Cowlitz River upstream from Mossyrock and Mayfield dams in Lewis County, Washington. In accordance with FERC's relicensing of the Cowlitz Hydroelectric Project in the 1990's, SFO measurements were implemented as part of an effort to reintroduce anadromous fish to the Cowlitz River. The original design implemented at Cowlitz Falls Dam was based on the successful SFO development at Wells Dam, which is also a hydrocombine dam, and consisted of baffle panels with a narrow and very deep transition screen. Physical modeling studies were used as a design aid while developing the original SFO screen configuration. This screen was later abandoned for a number of reasons. Field studies and CFD models were used to find the best baffle panel configuration to attract fish.

Various guidance technologies have been employed to increase FCE (Darland et al. 2001a; Evans et al. 2001; Darland et al. 2001b; Hausmann et al. 2001; Farley et al. 2003). Strobe lights have been used to deter fish from entering the induction slots (Evan et al. 2001), and the baffle panel has been reconfigured (Hausmann et al. 2001). Hausmann et al. (2001) found that the experimental panel configuration collected twice as many steelhead compared to standard baffle panel configuration. Subsequent research explored using induced turbulence to guide juvenile salmonids to the flume entrances (Darland et al. 2001b), but without noticeable improvement in FCE, though these results may have been confounded by the entrance effects described later in this section. Other research efforts have focused on juvenile salmonid behavior within a few yards of the flume entrance to understand why fish reject passage into the flume entrance after the fish have passed into the SFO structure. In 2001, research concentrated on altering the flow pattern to create constant acceleration into the flume entrance to increase fish collection and reduce delay (Farley at el. 2003).

A radio telemetry study was completed in 2001 to track the downstream migration behavior of steelhead and cutthroat trout, determine if a modified flume entrance could increase juvenile salmon collection, and establish baseline information on the migration behavior of juvenile sea-run trout. Travel times, migration rates, and residence times of radio tagged fish were dependent on flow characteristics and upstream travel behavior, as well as other factors. Overall, fish migrated quickly to the dam, but took longer periods of time to find a passage route through the dam. Data indicated that a high percentage of the fish were being attracted into the area between the baffle panels and the spillway gate fish flumes. The fish were, however, rejecting the abrupt flume entrances at the spillway gate face. It was concluded that installing a wide and somewhat deeper entrance to the fish screen with the proper transition (meeting NOAA criteria) from the low velocity area to the higher velocity flume flow should improve fish passage.

Spill Bay 3 North was chosen as the future location for the new SFO to improve fish collection efficiency. One dimensional hydraulic profile calculations were used to calculate the hydraulic profile in the fish screen channel and develop the required screen geometry of the V-shaped fish flume with a subcritical entrance flow regime. The V-shaped fish flume is shown in profile in Figure 3-30. A 3-D CFD model was used to develop the head loss coefficient distribution and appropriate backing plate porosity to meet the established performance criteria at the dominant turbine operating load. To validate the flow field calculated by the CFD model, field data were collected from the flow barrier baffle panel above the turbine intake trashracks to the fish transport flumes and compared with results from a CFD model of the spillway. Because the CFD model was a steady-state, rigid-lid model, it could not account for all variations in the water surface and transient flow features that may exist at the project site; hence, field adjustment was required.

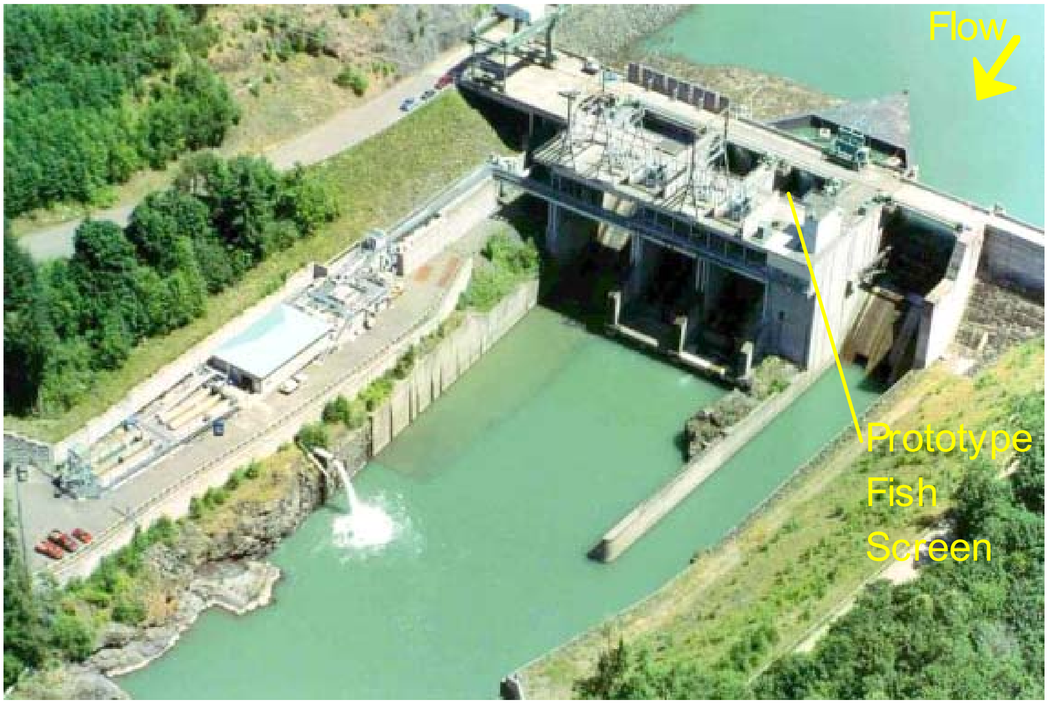


Figure 3-29. Aerial photo of Cowlitz Dam

Field velocity data were collected at seven measurement cross sections to determine the flow through each screen panel and average approach velocity at each screen panel. The backing plate porosities were then adjusted through a series of iterations to balance the approach flow velocity distribution. Once the final backing plate configuration was set, point velocities were measured along the screen panel vertical centerline to confirm that the hydraulic performance of the prototype fish screen met the design criteria. These criteria included a fish collection entrance velocity between 0.46 and 1.36 fps, a fish screen approach velocity component of less than 0.4 fps, a fish screen sweeping velocity component that is greater than the normal component, a fish screen transport velocity between 0.8 and 4.6 fps, a transport velocity gradient between 0 and 0.2 fps/ft, and a bypass flume entrance velocity of greater than 7 fps. The verification field test data met the hydraulic performance goals. The system was determined to have the desired fish attraction flow and a smooth acceleration up the flume.

Although all hydraulic criteria were satisfied and fish were observed entering the bypass flume, other juveniles were observed rejecting the SFO about 30 ft into the flume. At the rejection location, there is a sharp increase in transport velocity, a change in the floor geometry, and the termination of the screens. It is likely that the fish are deterred from progressing toward the flume entrance because of this combination of factors. During the 2007 field program, the fish flume flow and channel transport velocity gradient will be decreased, which should decrease fish rejection at this location and increase FCE. Other future plans include implementing hydraulic adjustments and shading the SFO to attempt to improve fish retention.

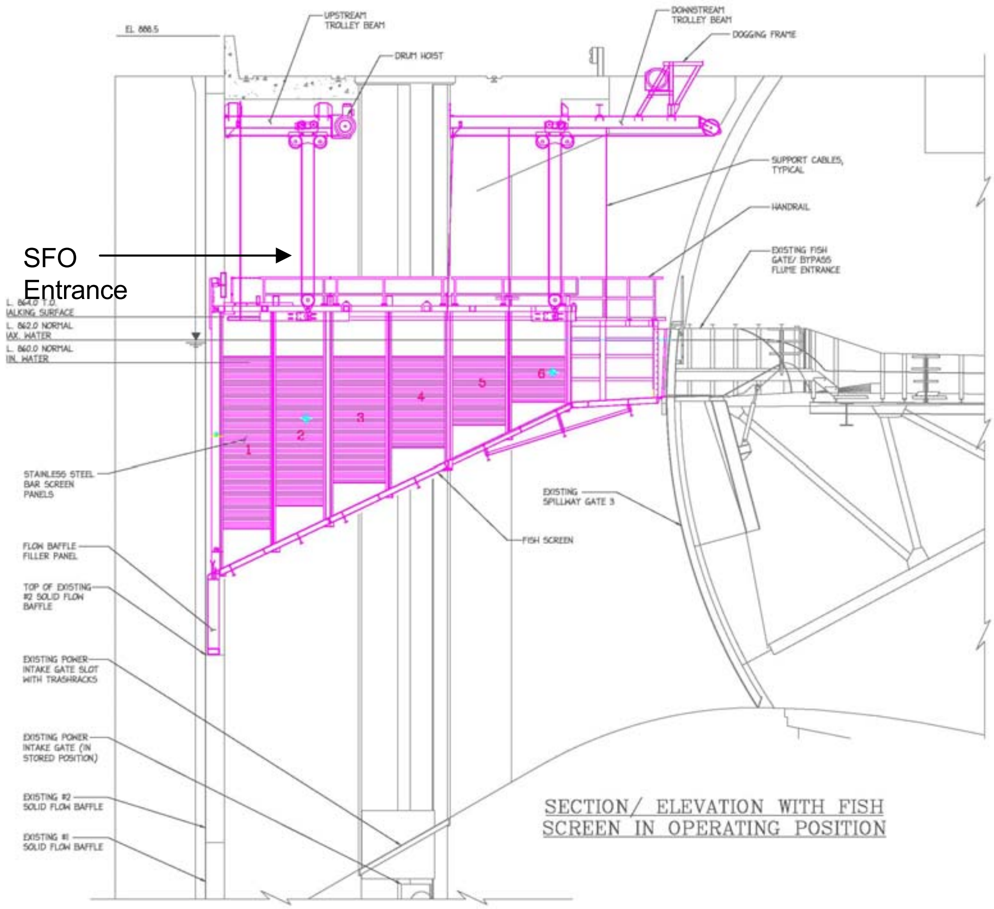


Figure 3-30. Cowlitz Falls SFO screen channel profile

The mean of average annual FCE estimates from 1997-2002 and 2006 indicate that 48% of steelhead, 30% of coho, and 21% of Chinook were collected at Cowlitz Falls Dam (see Table 3-16; BiOp 2004; SFO Presentation 2006). As reported in the BiOp (2004), the proportion of steelhead (81%) and age 0+ Chinook (56%) detected near the bypass system suggest that further improvement of entrance efficiency is possible. The key finding, or lesson learned from the Cowlitz SFO development thus far is that abrupt changes in transport velocity coupled with dramatic changes in channel geometry may lead to fish rejection.

Table 3-16. Biological performance indices for the Cowlitz Falls SFO

(FCE estimates are averaged over 1997-2002, 2006.)

Species	Fish Collection Efficiency
Steelhead	0.48
Yearling Chinook	0.21
Coho	0.30

3.5.3 Baker

The Baker River Hydroelectric Project, located in northwestern Washington State, consists of the Upper and Lower Baker dams. The dams are owned and operated by Puget Sound Energy (PSE). Upper Baker Dam has a cul-de-sac layout, shown in Figure 3-31, with a powerhouse capacity of 5,050 cfs. Currently, the central element of the downstream passage facilities at the Upper Baker River Project is a Floating Surface Collector (FSC), also referred to as a "gulper". The gulper was installed in 1960 to remediate declining sockeye populations on the Baker River. The gulper creates a near surface flow by pumping 100 -130 cfs of water through a louver system to attract fish to the entrance of the FSC (Wayne 1961). The fish entering the FSC are transported to a fish trap, hauled downstream of the dam, and released. Since the 1960s, PSE has made a number of improvements to the gulper, including the addition of full depth guide nets. These nets guide fish to the surface collector, and prevent them from entering the turbine intakes. To further improve the juvenile FCE at the Upper Baker Dam, PSE is designing a new FSC system that was selected and developed as a result of several years of collaborative consultation and research conducted by engineers and biologists representing resource agencies, Native American tribes, and PSE, as team members of the Fish Passage Technical Working Group (FPTWG). The FPTWG conceived and evaluated over 100 downstream passage concepts and alternatives over a 3-year period, culminating with the selection of new FSCs at both Upper and Lower Baker Dams.

Preliminary engineering design development, which began in June 2003, has included a workshop of experts, several site visits to observe operating surface collection facilities, and engineering design of the key components, including hydraulic physical and numerical modeling of these systems. The main components of the new system are a new FSC (shown in Figure 3-32), a net transition structure (NTS), and guide nets extending from the NTS to the forebay shorelines. Powerhouse operations (on or off), FSC size (575 or 1,000 cfs), and geometric features of the FSC and guide nets have the potential to influence forebay flow patterns, and thus impact attraction and collection of migrant fish.

To aid in the design of the FSC, several 3-D CFD model studies of the Upper Baker Dam forebay have been completed. The main objectives of these model studies were to determine the appropriate position of the FSC and guide nets; optimize the flow patterns in the forebay, near the guide nets, and at the entrance to the NTS for guidance of fish to the NTS; confirm that flow patterns were appropriate for fish guidance at other flows, powerhouse operations and reservoir elevations; determine hydraulic loads on guide nets and the FSC during PMF spill conditions; evaluate the effect of various intake configurations; and minimize the water quality impact of pump discharge jets. The forebay flow patterns calculated by the CFD models were used as a surrogate for fish movement because flow is thought to be the controllable factor with the highest influence on fish migratory behavior. Forebay flow conditions believed beneficial for fish passage were developed based on biological studies, a reservoir passage workshop, and suggestions from the FPTWG. Positive sweeping velocity (downstream along the guide nets) on the guide nets was identified as the most important criterion for evaluating model results.

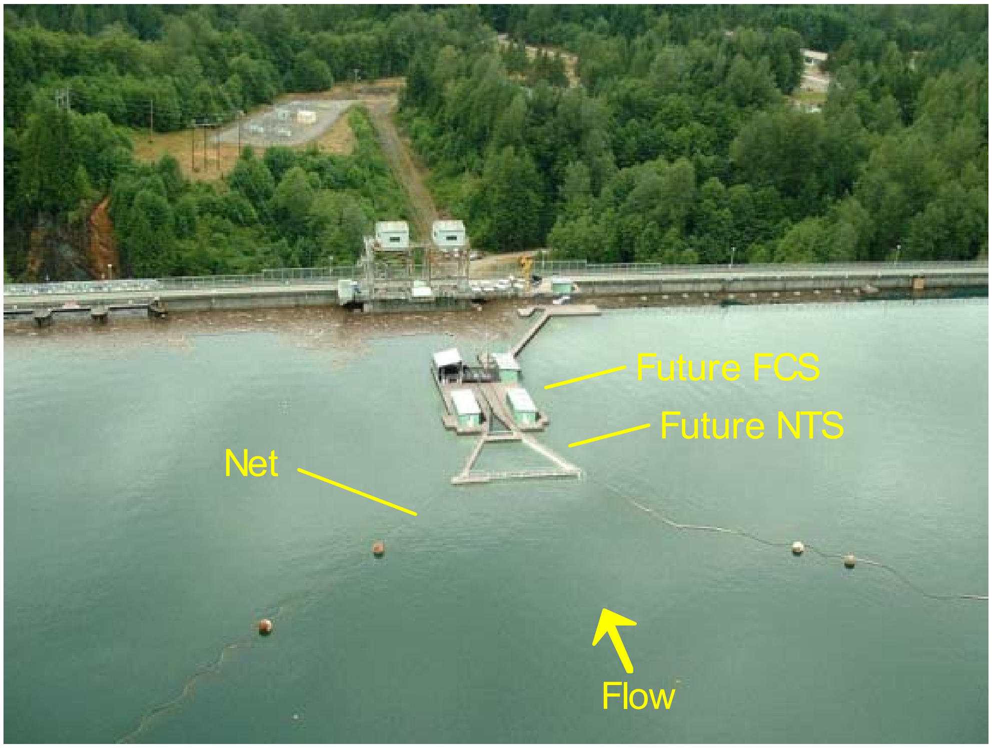


Figure 3-31. Aerial photo of Upper Baker Dam

The fish passage facilities are being developed in two phases. During Phase 1, the subcritical entrance flow through the FSC will be 575 cfs and the FSC intake flow will be discharged back to the forebay with primary and secondary pumps. If subsequent biological evaluations show that performance criteria are not achieved, the design of the FSC will be modified for the increased flow capacity of 1,000 cfs during the second phase. The performance criteria for the new facility are 95% juvenile collection, 98% transport and holding, 80% reservoir passage and survival, and 75% through these combined. The existing FSC (gulper), with a subcritical capacity of 130 cfs, is significantly smaller than the proposed FSC. The increased hydraulic capacity and screening system improvements of the proposed FSC are expected to improve the fish passage effectiveness at the project site. Design of the new FSC is slated to be completed in 2007.

The key to the success of the existing Baker SFO, and the future FSC, is using guide nets to direct the fish towards the FSC. The existing and future net spans the full depth of the reservoir, and fish have no passage option, other than the FSC.

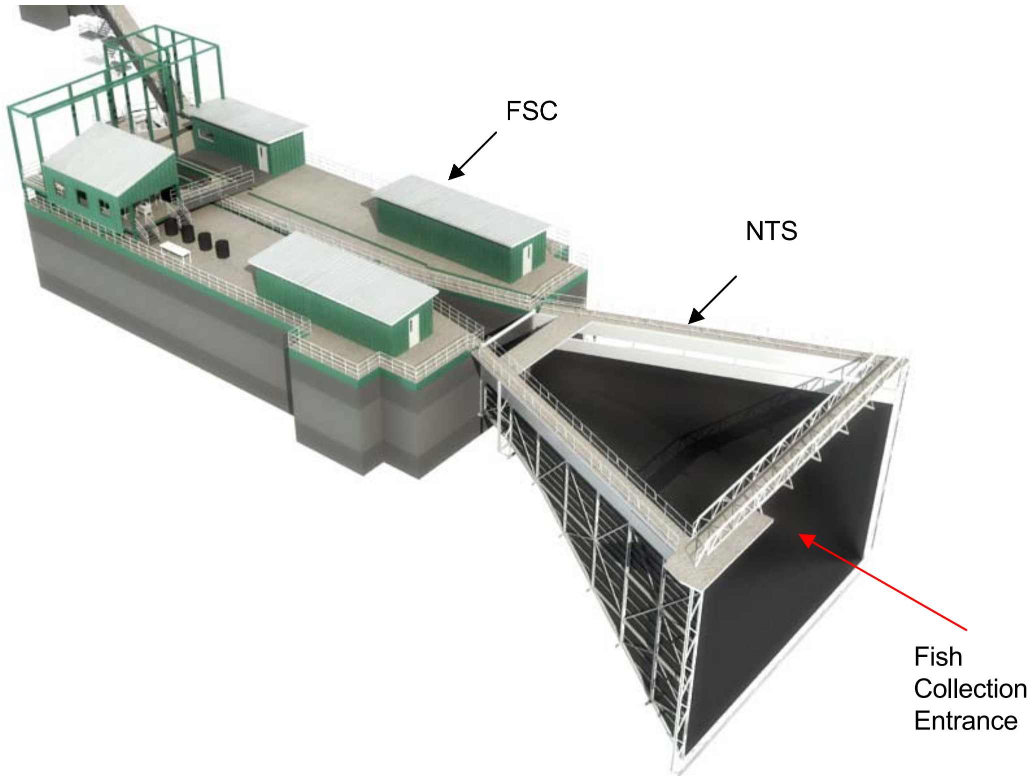


Figure 3-32. Upper Baker future FSC schematic

3.5.4 Round Butte

Portland General Electric's (PGE's) Round Butte Hydroelectric Project, located on the Deschutes River, near Madras, Oregon, has a cul-de-sac dam layout, as shown in Figure 3-33. SFO development is required to collect juvenile fish and improve lower Deschutes River water quality. The design and construction of a Selective Water Withdrawal (SWW) structure, a floating forebay collection structure, is intended to accomplish the fish collection and water quality goals and be a central component of the comprehensive fish passage program. The fish collection and water quality goals are being met through design of a combined facility because the lake hydrodynamics that drive the water quality requirements and present fish collection challenges are completely interrelated. The program is being designed with an ultimate goal of reintroduction of anadromous fish – salmon and steelhead – to the Upper Deschutes River system above the project.

Numerical models were used to determine the effects of the SWW structure on flow patterns and temperatures in the nearfield forebay where the SWW tower will be constructed, the lower Deschutes River, and Lake Billy Chinook. The numerical modeling of Lake Billy Chinook, formed by Round Butte Dam, has predicted that SWW from above and below the thermocline during different seasons can modify the lake stratification and resulting current patterns. SWW will be used to enhance surface water movement toward the project forebay to improve the potential for fish discovery of the SWW and successful operation of the SFO in the forebay. SWW will also be used to manage outflow water temperatures throughout the year to meet water quality standards and maintain the natural water temperatures that the fish are accustomed to.

Figure 3-33. Aerial photo of Round Butte Dam

A number of design concepts for achieving SWW and fish collection were investigated, and a final concept was selected, shown in Figure 3-34. The detailed design of the selected SWW concept is proceeding. Two physical hydraulic model studies of the SWW facility were completed in support of the detailed SWW design. A General SWW model was used to investigate flow entering the Fish Collection Entrances, passing through the Selective Withdrawal Top structure, down the Vertical Flow Conduit, through the Selective Withdrawal Bottom Structure, and entering the existing intake, or passing directly through the bottom structure into the existing intake. The smaller flows and dimensions of the fish passage system from the capture sections at the ends of the V-screens through the intake to the bypass conduit required investigation in a more detailed model. The SWW will have two fish collection entrances, each with a subcritical entrance flow of 3,000 cfs.

Both biological and hydraulic field studies have been completed in support of the SWW design. Hydraulic field tests have been performed to document the current patterns of Lake Billy Chinook, including releasing drogues under current normal conditions while using spill to simulate surface water withdrawal, using dye to trace water movement, and using current flow measurement with ADCP equipment. The biological evaluations included studying biofouling at a screen test facility at Round Butte and testing a 20-inch Hidrostal Fish Pump at the Klamath A Canal for passing salmonids up to 15 inches.

The SWW project is currently in the design phase, and is scheduled for construction in 2008 and start-up in 2009. The biological performance will be evaluated once the system is in operation.

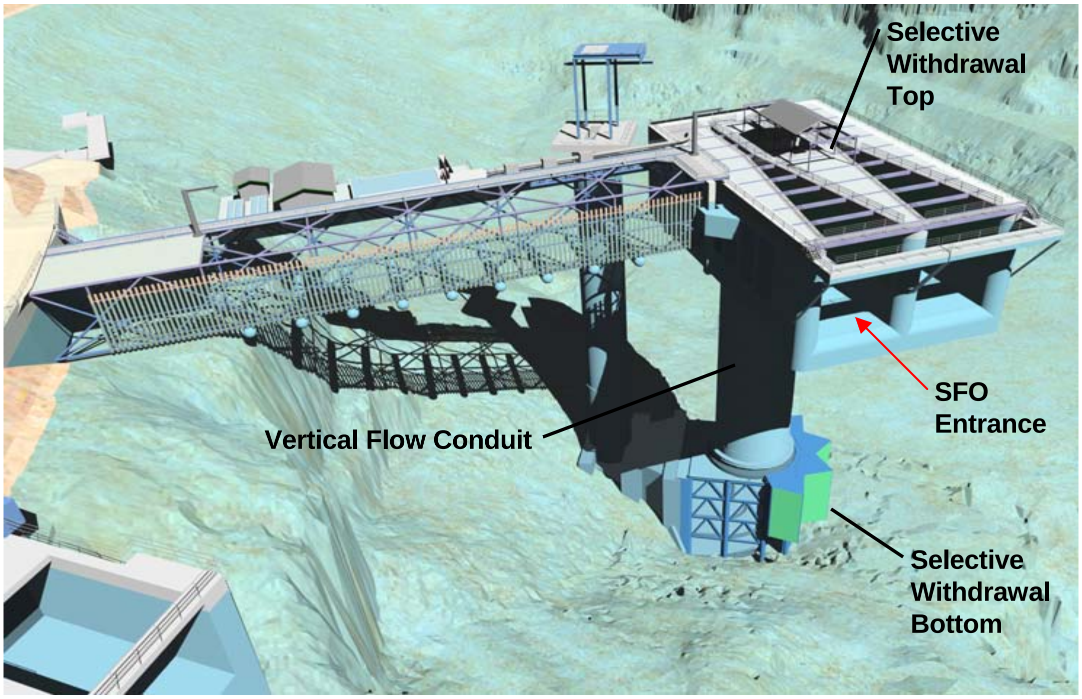


Figure 3-34. Round Butte SWW schematic

3.5.5 Willamette

The Willamette Falls complex, located on the Willamette River near Oregon City, Oregon, consists of the J-shaped Willamette Falls, a lock system, a large fish ladder, and the T.W. Sullivan Hydroelectric Plant, owned and operated by PGE, shown in Figure 3-35. Development of juvenile fish passage is required as part of the Sullivan Plant relicensing agreement. The only existing fish passage measure at the site is an Eicher Screen system located in one of the Sullivan Plant units.

PGE has recently completed construction of an SFO in the Sullivan forebay by converting an existing siphon spillway into a 500-cfs fish bypass spillway. The design of the bypass spillway was developed with the aid of several physical models. A 1:12 scale physical model of the forebay was used to develop improvements to a louver-type trashrack so that it could be used to guide fish toward the spillway entrance, a 1:8 scale physical model was used to develop design details of the bypass, and a 1:30 scale physical model of the tailrace was used to select the bypass outfall location. Start-up of the bypass spillway occurred in early 2007, and biological monitoring of the bypass is scheduled for the spring and summer of 2007.

In addition to the bypass spillway, PGE is currently constructing a flow control structure (FCS) near the apex of the falls, which will provide another controlled fish passage route. The FCS has been designed to safely pass fish over the falls without negatively affecting the performance of a nearby existing adult fish ladder. The 1:30 scale tailrace model was expanded to include the FCS and was then used to support the FCS design. The FCS start-up is scheduled for early 2008, to be followed by biological monitoring.

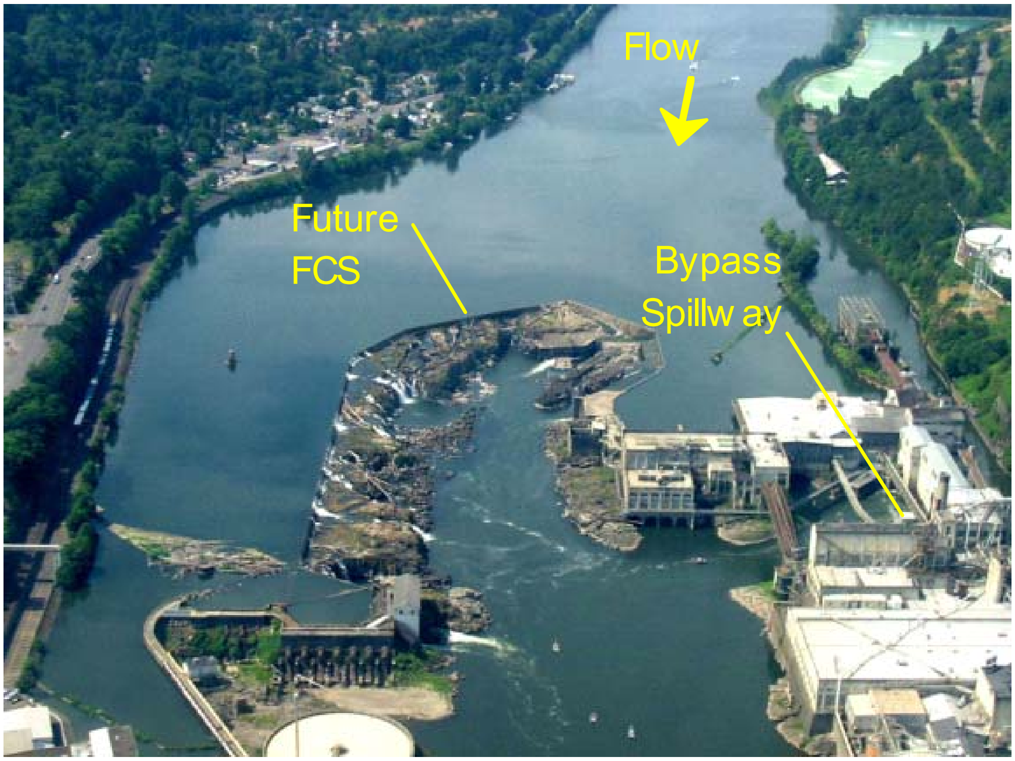


Figure 3-35. Aerial photo of Willamette Falls

3.5.6 North Fork

PGE's North Fork Hydroelectric Project, on the Clackamas River in Estacada, Oregon, is a cul-de-sac dam, shown in Figure 3-36, with a 6,000-cfs hydraulic capacity powerhouse. A combination adult and juvenile fish surface collector was constructed in 1958. The facility, located on the spill bay side of the dam, has an attraction flow of 240 cfs. Once fish enter the bypass system, they travel 1.7 ft until they are diverted into a holding tank. PIT tag, radio tag, sonic tag, and hydroacoustic testing were completed to asses the biological performance of the collector. From these tests it was determined that fish tend to be surface-orientated and travel parallel to the dam, and that most fish approached the SFO along the south shore of the forebay. FCE, the median reservoir residence time, and fish passage related to flow were also determined from these studies (see Appendix C). This facility is currently in operation; however, the existing screens will need to be replaced to meet the current size criteria.

A new 3,000-cfs surface collector directly connected to the turbine intake was considered to complement the existing SFO. This idea was discarded, however, because of the related cost, the belief that passage goals could be achieved with a smaller collector, and the potential negative impacts to juveniles rearing in the reservoir and downstream water quality. Next, an FSC located in front of the intake was considered to supplement the existing SFO. In 2004, a CFD model was used to assess attraction flows from 500 to 1,500 cfs. Based on the model results, PGE negotiated a settlement to build a subcritical 1,000-cfs surface collector. This collector is currently in the design stage and is expected to be installed in 2012.

Figure 3-36. Aerial photo of North Fork Dam

3.5.7 Howard Hanson

The Corps' Howard Hanson Dam, located on the Green River in Palmer, Washington, is shown in Figure 3-37. The dam is a flood control and water storage dam only; no power is generated at this dam. The reservoir has a very large (100-ft) range in operating water level. In an attempt to restore a self-sustaining fish run to the Upper Green River, an SFO facility is currently being developed for the Howard Hanson Dam. Multiple near-surface submerged collectors both with and without an adjustable elevation surface collector, which would cover the top 20 ft of the reservoir elevation range, were investigated as SFO possibilities at Howard Hanson Dam. The multiple near-surface submerged collectors are a series of stacked, high-velocity MIS screened collectors with a subcritical entrance flow regime, shown in Figure 3-38, that will operate based on the forebay elevation. At high forebay elevations, the top one or two collectors will operate. As the forebay elevation decreases the lower collectors will be operated instead. With the FSC configuration, the floating collector would replace the topmost stationary collector in the multiple near-surface submerged collectors. Physical hydraulic modeling was used to refine the entrance shape of the submerged collectors to reduce fish delay and to improve screen hydraulics. The submerged collectors were designed so the screen approach velocity would not exceed the sustained swimming capability of juvenile salmonids (USACE 2000). CFD modeling was used to study forebay currents for a variety of forebay elevations and SFO and low-level outlet operations. The adjustable elevation surface collector was discarded as a design alternative because it had a large impact on the project budget and would have caused unacceptable delays in the design, construction, and operation of the new facility.

Figure 3-37. Aerial photo of Howard Hanson Dam

The multiple near-surface submerged collectors are still being tested in the physical model in conjunction with construction of the facility. After the facility is operational, the performance of the system will be monitored and, if warranted, a small-scale surface collector may be added in the future, above the existing collectors.

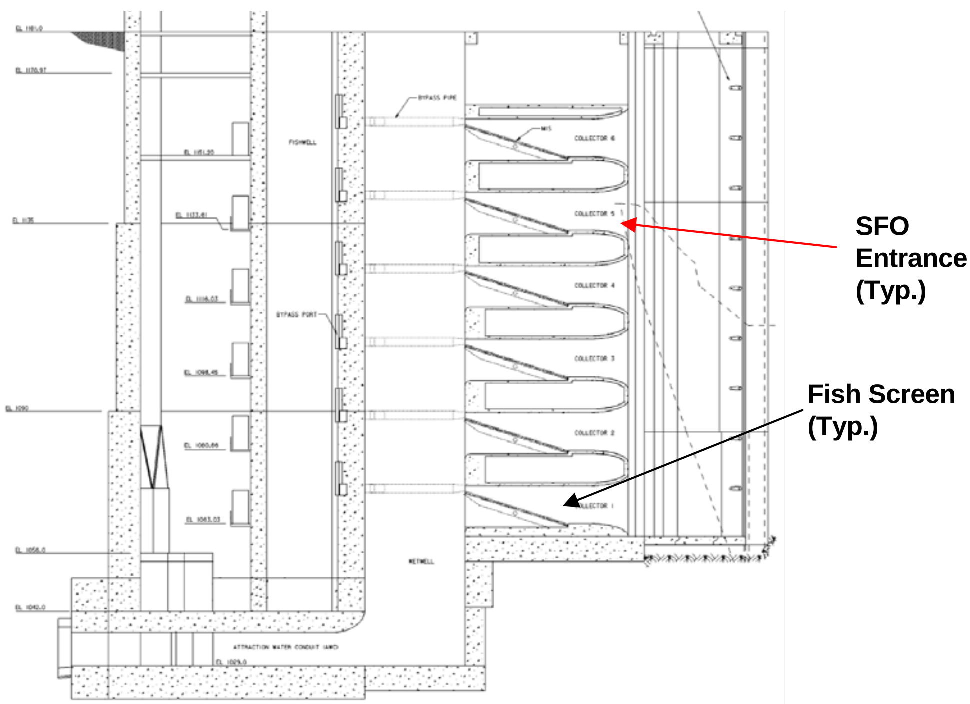


Figure 3-38. Multiple near-surface submerged collector profile

4.0 Analysis and Synthesis

This chapter contains analysis and synthesis of hydraulic and biological data from many of the SFOs covered in the synopses in the previous chapter. This effort will contribute to the main objectives of this compendium, which, to reiterate, are to: 1) develop a single reference documenting SFO development in the Pacific Northwest; and 2) provide lessons learned from successes and failures and general design and operational considerations for biologists and engineers to use in future SFO development. The chapter begins with the derivation and analysis of a biological performance index for SFOs. This is followed by an analysis of SFO features and factors influencing SFO performance. The chapter culminates with summaries for many of the SFOs we studied.

The analysis and synthesis in this chapter focused on the forebay components of an SFO: the Approach, Discovery, and Decision Zones. Smolt survival In the Conveyance and Outfall Zones has been estimated to evaluate the safety of the route. Survival evaluations typically came into play after the collection potential of the SFO was demonstrated and the prototype or production unit was in place. Conditions in the conveyance and outfall areas can be generally configured and manipulated to produce acceptable fish passage conditions, although, in our view, further research is needed in this area. In all cases, the SFOs evaluated achieved survival rates acceptable to fishery agencies responsible for authorizing their use. Further research on fish injury/survival during post-construction monitoring and evaluation, however, is definitely warranted as this subject matter is not as well documented as forebay collection. For these reasons, we do not treat conveyance and outfall conditions as factors in this particular analysis and synthesis of SFO performance. Conveyance and outfall, however, are important, essential components of SFOs and will be discussed in Chapter 5.

4.1 Physical Characteristics of Project Layouts and SFO Hydraulic Profiles

This section synthesizes project layouts and SFO hydraulic profiles by displaying similar data for all locations on the same page allowing one to compare and contrast the locations to synthesize the information.

4.1.1 Project Layouts

The plan view layouts of the projects are presented in Figure 4-1. Pertinent features are the reservoir shape and dam configuration, and the relative locations of the powerhouse, spillway, and active SFO outlet(s). There are different forebay geometries. Wanapum, Priest Rapids, and McNary all have wide expansive forebays with the project structures flanked by long earthen embankments. The remaining project forebays are narrower than these.

There are three main types of project layouts: linear across the river (Wells, Lower Granite, John Day, Little Goose, Lower Monumental, Ice Harbor, Priest Rapids, and McNary), Z-dams (Rocky Reach and The Dalles), and multiple project features split by islands (Rock Island and Bonneville). Wanapum is technically a Z-dam, but the cul-de-sac effect is not nearly as pronounced as for Rocky Reach and The Dalles. The relative layout of the project features of the Wells hydrocombine are unique, with the powerhouse, spillway, and multiple SFO entrances located together at the center of a linear dam. The Z-dam arrangement at Rocky Reach is much different than arrangements at Wanapum and The Dalles in that the spillway is located upstream from the powerhouse at Rocky Reach and downstream at Wanapum and The Dalles. All three projects have their single active SFO entrance located in the cul-de-sac near the downstream end of the powerhouse. The general flow pattern at Rocky Reach and The Dalles is an eddy, but is less clearly defined at Wanapum. The island-split projects, Rock Island and Bonneville, both have powerhouses located in channels near both banks and a central spillway, but with quite different SFO locations. At Bonneville, the two active SFOs are located at each powerhouse, while at Rock Island the central spillway contains multiple SFOs. The remaining projects are all linear and have single SFO entrances located in the spillway in the center of the dam.

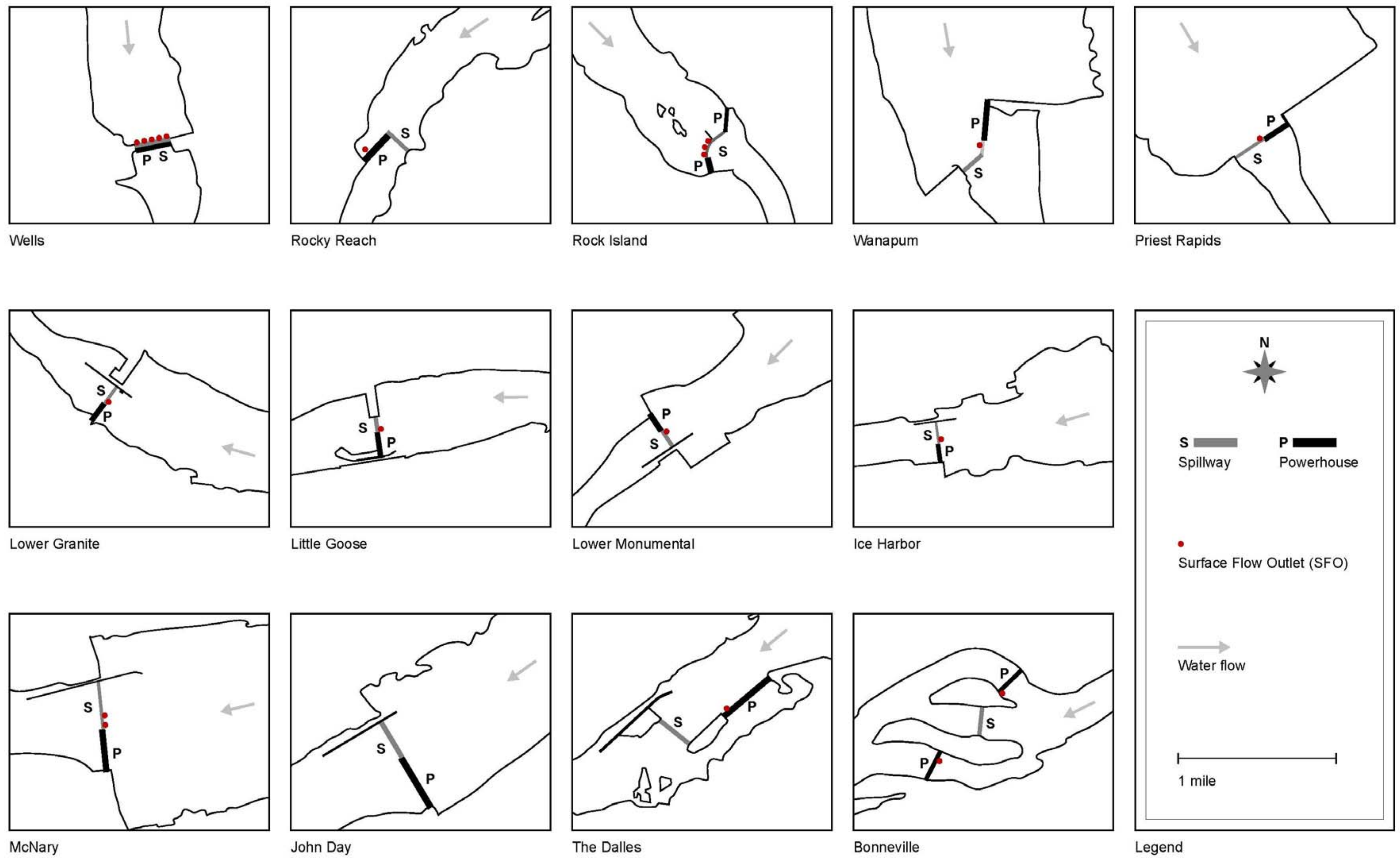


Figure 4-1. Project layouts (drawings by N. Johnson, PNNL)

4.1.2 Hydraulic Profiles

The hydraulic profile of flow entering each SFO was described by the entrance flow regime (defined in Section 2.2), velocity, velocity gradient, and acceleration of flow. To develop the hydraulic profile plots included in this section, we acquired available velocity data from physical hydraulic or CFD modeling of the various SFO entrances for which biological data were also available. For these data sets, we extracted velocities along a streamline that entered the vertical and lateral centerline of the SFO entrance at the entrance plane. The entrance plane was defined as the face of the pier or bulkhead structure that flow enters and where the lateral enclosure of the SFO begins. The velocity vector magnitude, V, was plotted versus distance, X, along the streamline, with the origin for the streamline stationed at the entrance plane, negative distances upstream from the plane, and positive distances downstream.

Velocity gradient, G, was calculated from the velocity data and the streamline stationing using the standard definition:

$$G = {}^{\Delta V}\!/_{\Delta X}\,, \tag{4.1}$$

where Δ denotes the change in values between stations. Velocity gradient is included in the plots as it is the parameter used to define acceptable rates of velocity change in the NOAA (2004) fish passage design guidelines. This guideline is based on the theory that fish can sense a velocity gradient along their body length. The NOAA guideline states that “to assure that fish move quickly into the bypass system, the rate increase in velocity between any two points in the screen/bypass system should not decrease and should not exceed 0.2 fps/ft” (NOAA 2004).

Acceleration, A, was included in the plots because it fits the classic physics definition by Newton’s second law of a force, F, experienced by a mass, m. Acceleration was calculated from the velocity data and streamline information using the standard definition:

$$A = \frac{\Delta V}{\Delta x} V_{avg}\,, \tag{4.2}$$

where V_{avg} is the average velocity between stations.

Many other hydraulic parameters have been identified by others (e.g., Goodwin et. al. 2006), which may influence fish behavior in the Decision Zone, such as fluid strain, the three-dimensional spatial rate of change of velocity in the fluid. However, the centerline velocity, velocity gradient, and acceleration were the only parameters in our investigation that could be readily derived from existing data for a number of the SFOs and therefore could provide a common currency for comparison.

The hydraulic profiles, presented in Figure 4-2, are annotated with the biological performance indices from the synopses in Chapter 3, with the entrance regime type (i.e., critical or subcritical) and the SFO collection flow, the latter giving a sense of dimension of the SFO.

The definition of critical versus subcritical flow regime hinges on the direction, upstream or downstream, of propagation of waves or flow disturbances. This physics-based definition may have little relevance to fish behavior. It is possible to have a critical entrance flow regime with flow velocities varying over a large range as a function of the flow depth. In our assessment, a more telling characteristic may be whether the velocity at the entrance is adequate to capture fish (V > 7 fps).

The RSWs, Bonneville 2nd Powerhouse Corner Collector, and The Dalles sluiceway are examples of SFOs with a critical entrance flow regime. Capture velocity is achieved at all entrances except The Dalles. Rocky

Reach, the B1 PSC, Cowlitz, and the Lower Granite SBC all have subcritical entrance regime and only the Lower Granite SBC reaches capture velocity. These examples demonstrate the irrelevance of entrance flow regime in achieving a capturing entrance velocity.

In our assessment of the hydraulic profiles, another important characteristic may be whether the flow approaching the entrance and/or capture location continues to accelerate smoothly, or if the acceleration is abrupt, or inconsistent with areas of deceleration. As noted earlier, the NOAA guidelines (NOAA. 2004) consider abrupt acceleration or deceleration of flow problematic in fish passage design and this is supported by anecdotal evidence from the projects we have assessed, i.e., the Rocky Reach prototype SFO and the Cowlitz Falls SFO.

The acceleration and velocity gradient profiles of the projects in Figure 4-2 fall into the following categories:

Smooth Acceleration – In this category, flow continues to accelerate smoothly and with a steadily increasing rate, with a gradient value in the range of less than 0.4 fps/ft or an acceleration of less than 3 ft/sec^2, through capture, or at least well past the entrance plane for SFOs where capture occurs further downstream in the system. Examples of this profile type are all of the RSWs, the B1 PSC, and the Rocky Reach corner collector.

Abrupt Acceleration – In this category, acceleration occurs more abruptly, with gradient values greater than 0.4 fps/ft and up to 1.5 fps/ft, and acceleration of greater than 3 ft/sec^2 and up to 20 ft/sec^2. Both the B2 Corner Collector and the Lower Granite SBC fall in this category.

Inconsistent Acceleration – This category is marked by a profile where the velocity gradient and acceleration are low (< 0.2 fps/ft and 1 ft/sec^2) but somewhat erratic, with values increasing and decreasing, before capture velocity is achieved. Only Cowlitz Falls was in this category.

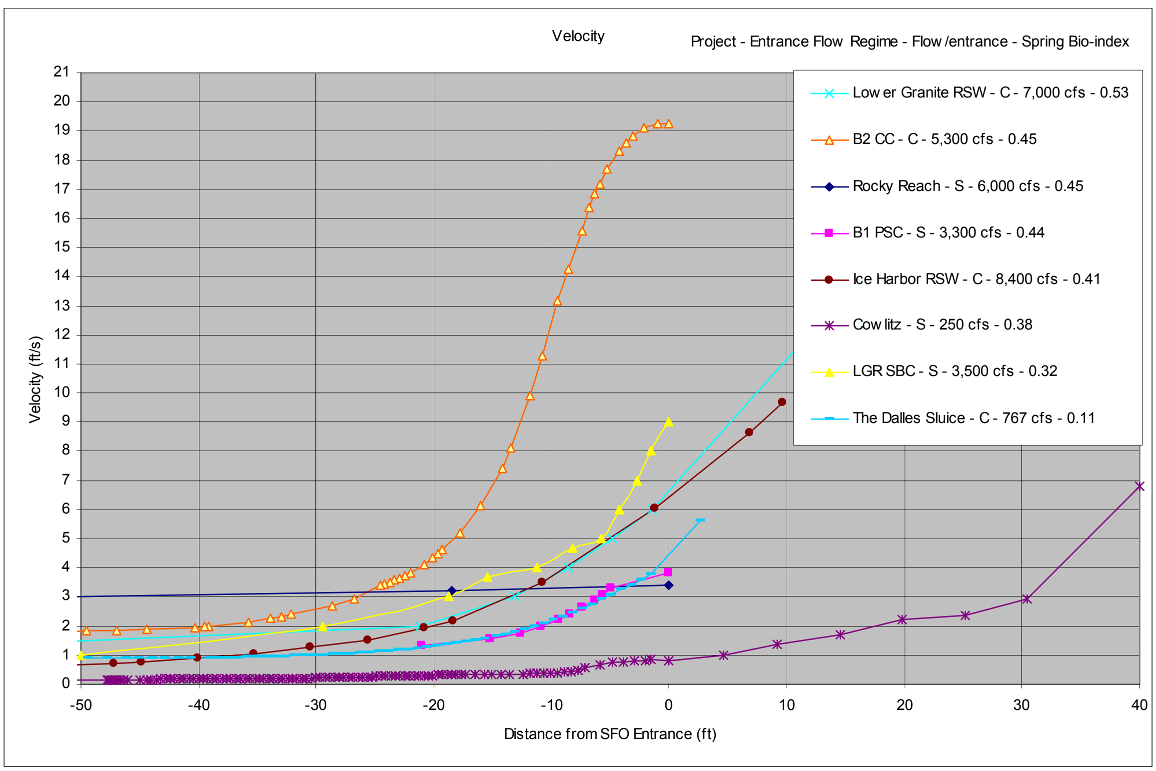


Figure 4-2 (a). Velocity Profiles

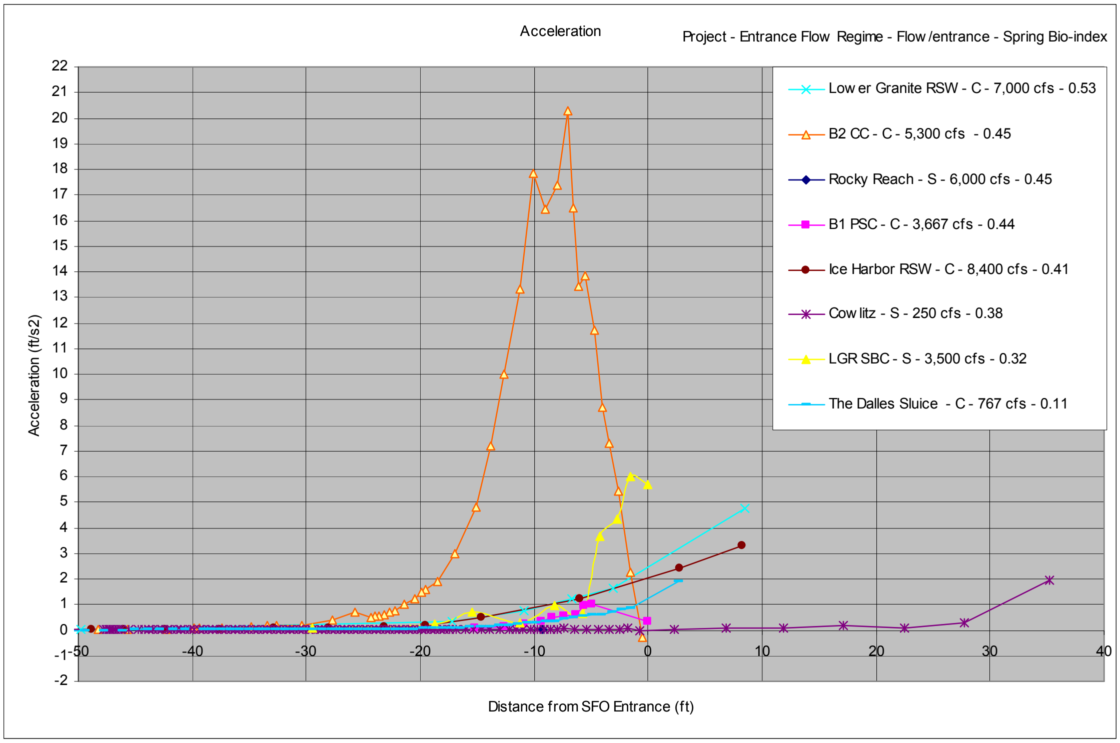


Figure 4-2 (b). Acceleration Profiles

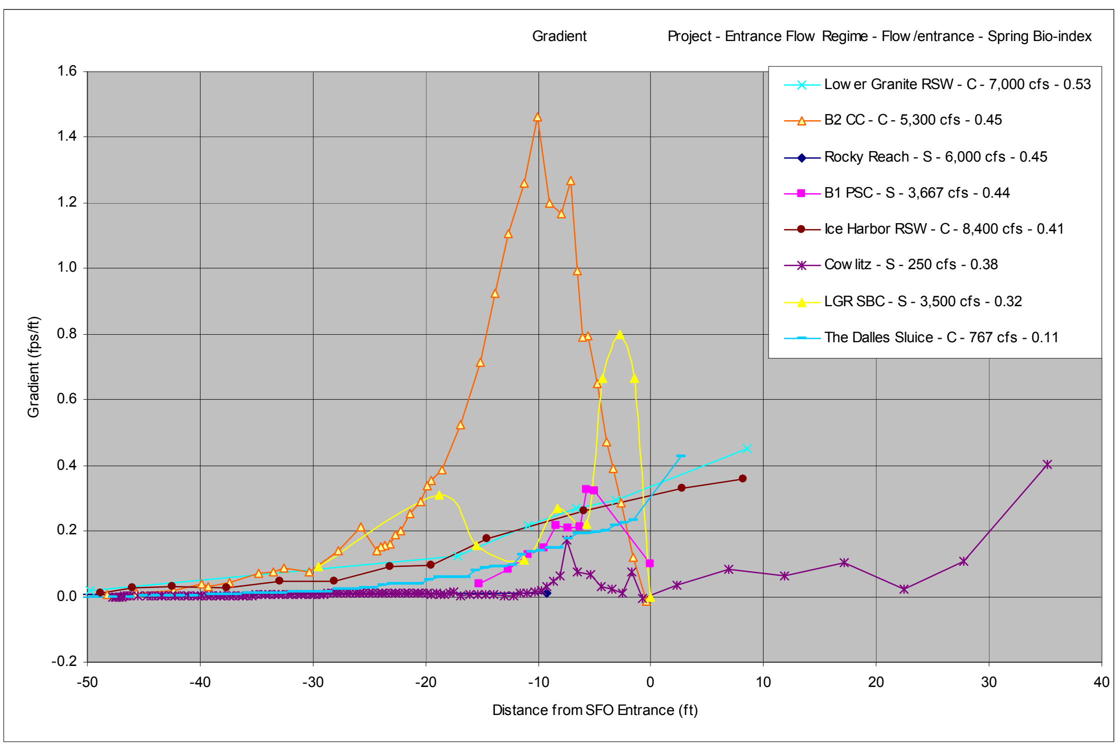


Figure 4-2 (c). Velocity Gradient Profiles

4.1.3 Key Physical Characteristics

As described later in Section 4.4, we identified a number of physical features of SFOs that, in our assessment, represent key functions pertaining to SFOs. We have transferred the numerical data describing these features from the sources in the preceding hydraulic profile section and the Master SFO Hydraulic Characteristics Matrix in Appendix B to Table 4-1, to allow easier review and comparison. The features include the SFO flow (Q) as a percentage of the powerhouse hydraulic capacity, the number of SFO entrances, the depth of the SFO entrance invert, SFO flow (Q) per entrance, the maximum acceleration of flow entering the SFO, the width of the SFO fish and flow transport channel at the location where capture velocity occurs, and water velocity at the plane of the entrance. For the last parameter, entrance velocity, note that, while RSWs do not achieve a velocity greater than 7 fps at the entrance plane, they do a short distance downstream.

Table 4-1. Key physical characteristics for each project.

Project	SFO Type	SFO Q Fraction (%)	No. Entrances	Invert Depth (ft)	SFO Q per Entrance (kcfs)	Acceleration (fps^2)	Width at Capture (ft)	Entrance V(fps)
Wells	Retrofit	5	5	72	2.2	nd	~50	1.9
Lower Granite	Surface Spill RSW	5.4	1	26	7.0	2.5	48	3.9
Bonneville 1st	Sluiceway	1.1	3	7	1.5	nd	21	3.4
Bonneville 2nd	Sluice Corner Collector	3.5	1	22	5.3	5	15	16.1
Rocky Reach	Forebay Corner Collector	2.7	1	60	6.0	1	~8	2.9
Bonneville 1st	Retrofit PSC	14.7	6	45	Na	1	12	3.7
Ice Harbor	Surface Spill RSW	7.9	1	24	8.4	2.5	48	5.5
Cowlitz Falls	Retrofit	4.8	1	20	Na	2	2	0.6
Lower Granite	Retrofit SBC	2.7	1	28	3.5	5	16	7.8
Ice Harbor	Sluiceway	5.7	3	4	2.7	nd	18	12.5
Wanapum	Surface Spill	1.2	1	50	1.4	nd	50	1.8
The Dalles	Sluiceway	1.6	6	9	0.7	2	~20	4.2
Wanapum	Sluiceway	1.7	1	9	2.0	nd	20	10.9
Priest Rapids	Sluiceway	1.3	1	9	2.0	nd	20	10.9
Wanapum	Retrofit	1.2	1	50	1.4	nd	~5	~2

4.2 Biological Performance by SFO and Species

Based on our review of the literature we sought to formulate common indices that could be used to compare biological performance across SFOs. This proved to be a challenging venture in that investigators used different tools (radio, acoustic tags, or fixed location hydroacoustics) that yielded differing spatial resolution. We arrived at the "Bio-index" described below.

4.2.1 Methods

We initially identified three indices as informative and reflective of fish responses in different spatial zones attending SFOs in the forebay (Section 3.1.3). Discovery efficiency (DE) characterizes the probability that smolts will encounter an SFO flow net. It reflects migratory behaviors in the distant Approach Zone (Figure 2-3) as fish move toward the dam and the Discovery Zone in the forebay. Of fish arriving near the entrance (Decision Zone), the proportion estimated to enter and pass through the SFO is expressed as entrance efficiency (EE). Entrance efficiency reflects smolt behavior and decisions near and in the entrance of the SFO. Fish collection efficiency (FCE) is the proportion of smolts passing a dam that does so through the SFO. It is the joint probability of discovering and passing into the SFO, i.e., FCE = DE * EE. The studies reviewed rarely reported estimates of DE and EE that reflected spatially-specific behavior and processes (see Appendices B and C), which constitutes a deficiency in our view. Thus, obtaining a diverse set of indices common to most SFOs was problematic. In fact, only one index was regularly reported across most SFOs - FCE.

To formulate a biological index of SFO performance based on FCE, called the "Bio-index", we took the following steps:

Step 1 - Populate the master table (Appendix B) with estimates of DE, EE, FCE, etc. for each dam, species, and study year. In our review of technical reports, we focused on studies that homed in on production SFOs. However, we also compiled data for prototypes that were substantially evaluated and offered lessons learned. The SFOs we selected and the associated performance estimates are presented in Appendix B. This detailed base information was subsequently parsed and summarized to produce the various tables and figures appearing in this section of the report.

Step 2 - Summarize performance data, averaging across study year for each SFO separately. The purpose was to distill a general set of performance indices (DE, EE, FCE) for each site to depict overall performance. At sites where multiple years of data were available we averaged estimates to yield overall species-specific indices for the SFO. This information is reported in the project-specific synopses, often in tabular form, in Chapter 3.

Step 3 - Develop the bio-index based on FCE as reported for spring and summer migration periods. This index is used to characterize overall SFO performance, providing a common currency to permit comparisons across different types of SFOs. The bio-index was calculated by averaging FCE estimates from all available data across all species (telemetry estimates) and the run-at-large (hydroacoustic estimates) (Appendix B).

Step 4 - Use the FCE bio-index for as the basis for assessing SFO performance and facilitating comparisons among SFOs. The set of SFOs we elected to index and analyze includes sites where smolts have a choice among several passage routes. As such, we did not include sites like the Baker gulper, which better resembles a trap and a barrier net that occludes alternative passage routes. Similarly we did not select Mayfield, since the louver system acts like a diversion screen rather than an unobstructed portal typical of the SFOs on the Columbia-Snake system.

4.2.2 Results

bio-indices were available for 15 SFOs, mostly at Corps and PUD dams on the mainstem Columbia and Snake rivers (Table 4-2). Fewer SFOs were evaluated for summer-migrating subyearling Chinook salmon (n = 10) than spring-migrating yearling migrants (n = 15). For the spring migration period of yearling Chinook salmon, steelhead, and sockeye, bio-index values ranged from 0.003 to 0.89 (Table 4-2). For the summer migration period of subyearling Chinook salmon, bio-index values also ranged from 0.003 to 0.89 (Table 4-2). This represents the performance of existing production systems as well as select prototype SFOs that may not have been adopted. The best performing SFO according to this analysis was the retrofit baffle system at Wells Dam.

Prior to this synthesis, conventional wisdom seemed to indicate that summer performance was poorer than that observed for spring migrants. We found this not to be the case. On average, the bio-index values are nearly the same during both periods, at 0.33 in spring and 0.32 in summer (Table 4-2). Furthermore, at each SFO the seasonal values generally are the same, with the exception of the Rocky Reach forebay collector, for which only one year of subyearling Chinook salmon data were available.

Inspection of species-specific bio-indices (Table 4-3) reveals that on average across all SFOs and years of data, steelhead displayed the greatest proclivity (0.46) for using the SFO passage route. For spring migrants, sockeye exhibit the next highest score (0.37); however, performance of this species was only evaluated at one SFO in our set, the forebay collector at Rocky Reach Dam. Yearling and subyearling Chinook and coho salmon yielded similar index values of 0.27, 0.38, and 0.30, respectively.

Table 4-2. Bio-index data for spring and summer migration periods, as averaged across species for each project

(Data are from the bio-index table in Appendix B.)

Project	SFO	Bio-Index Spring	Bio-Index Summer
Bonneville First Powerhouse	Retrofit PSC	0.44	---*
Bonneville First Powerhouse	Sluiceway	0.46	0.52
Bonneville Second Powerhouse	Sluiceway B2CC	0.45	0.40
Cowlitz Falls	Retrofit Baffle	0.33	---
Ice Harbor	Sluiceway (1982, 83)	0.32	---
Ice Harbor	Surface Spill RSW	0.37	0.51
Lower Granite	Retrofit SBC	0.32	---
Lower Granite	Surface Spill RSW	0.49	0.44
Priest Rapids	Sluiceway	0.03	0.04
Rocky Reach	Forebay Collector	0.45	0.25
The Dalles	Sluiceway	0.11	0.07
Wanapum	Retrofit - SAC	0.003	0.003
Wanapum	Sluiceway	0.05	0.06
Wanapum	Surface Spill	0.17	---
Wells	Retrofit Baffle Bays	0.89	0.89
	Mean	0.33	0.32

*indicates no available data

Table 4-3. Bio-index data for each species, as averaged by SFO type across all SFOs appearing in Table 4-2

(Averages were calculated from the bio-index table in Appendix B. Data for "overall" are averages from all SFOs combined, not averages of the SFO types in the table. Data for the spring and summer bio-indices are also averages of the bio-indices over all SFOs in Appendix B.)

SFO Type	Yearling Chinook	Steelhead	Coho	Sockeye	Run-at-Large Spring	Bio-Index Spring	Subyearling Chinook	Run-at-Large Summer	Bio-Index Summer
Forebay Collector	0.30	0.67	---	0.37	---	0.45	0.25	---	0.25
Retrofit	0.31	0.38	0.30	---	0.44	0.40	---	0.45	0.45
Sluiceway	0.19	0.45	---	---	0.20	0.24	0.34	0.21	0.22
Surface Spill	0.34	0.48	---	---	0.38	0.34	0.64	0.32	0.41
Overall Mean	0.27	0.46	0.30	0.37	0.30	0.33	0.38	0.29	0.32

4.3 Biological/Physical Parameter Analysis

FCE provides only a general index of overall fish collection and passage performance. It does not permit us to readily determine the importance of far-field or near-field behaviors and prevailing physical conditions in the forebay, nor does it reflect conveyance or outfall performance. As a consequence, we were limited in our ability to ascertain effects of SFO configuration and hydraulic conditions with spatial specificity, which severely restricted analytical opportunities. This limitation is illustrated in some probative plots between the FCE-based bio-index and assorted physical parameters (Figure B-1 in Appendix B).

Most of the physical parameters treated as independent variables in our exploratory analyses (i.e., entrance dimensions and area, SFO unit discharge, and entrance velocity) would be expected to primarily affect response in the Decision Zone; however, as expected, there were no clear relationships with the coarse FCE bio-index. Even the parameters which would be expected to have a more far-ranging effect and impact on FCE, such as forebay depth, and SFO flow, were not associated statistically with the bio-index.

4.4 Synthesis of SFO Features

One of our objectives was to identify key features that contribute to the successful design and operation of an SFO. In order to formulate considerations for designing a successful SFO, we needed to identify and describe the characteristics of both good and poor performing SFOs. We identified ten features that in our assessment represent key functions pertaining to successful fish collection at surface flow outlets. These features include hydraulic, physical, and structural characteristics, which we spatially blocked into either the far-field (Discovery Zone) or near-field (Decision Zone).

<u>Discovery Zone Features</u>

Sill or Shallowing Forebay - The presence of a sill in the forebay, or more generally a situation where the bathymetry shallows along the approach path to the dam, serves to compress the vertical distribution of smolts closer to the surface. We expect this to be beneficial in that it increases the probability that fish will encounter the flow field of the SFO. For example, high performance at both Wells Dam and Bonneville Second powerhouse SFOs is believed to be enhanced because of relatively shallow forebays upstream of the SFO entrances.

Competing Far-field Flow Nets - The presence of prominent large-scale flow nets that draw substantial water volume away from an SFO entrance (e.g., spillway and turbines) can also draw fish away from the SFO intended target zone. This affects horizontal distribution of the population and reduces the probability that smolts will discover the SFO entrance; this is a negative factor. For example, at The Dalles Dam the location of the spillway in combination with high voluntary spill volumes draws smolts toward the spillway and away from the area of the powerhouse where an otherwise efficient sluiceway is located.

Optimal Entrance Location - Locating a SFO entrance where fish naturally congregate will increase discovery efficiency. In addition, physical and operational features that affect the horizontal distribution of the population and direct smolts to, or concentrate them near, an SFO entrance are optimal. In our review a variety of physical features were observed to concentrate fish in this manner including the following. If one or more of these features are evident, then the Entrance Location received a "✓" in Table 4-4.

- Entrances Along Migratory Paths - Smolts may exhibit prominent migratory paths en route to or along the dam. If these paths can be identified, deploying an SFO along the route will increase discovery efficiency. For example, both Lower Granite and Ice Harbor RSWs (which are considered higher level SFO performers in part because of their locations) were placed where smolts were observed to naturally migrate. In contrast, a lower level SFO performance example of this feature includes the Wanapum surface attraction channel that had lesser performance which, in part, was attributed to not having entrances located where fish were migrating and/or accumulating.

- Entrances at Fish Concentration Points Created by Currents or Eddies - Both Bonneville Dam B2 Corner Collector (with a strong eddy concentrating smolts near the entrance) and Rocky Reach forebay collector (with its entrance located in an area where smolts are known to congregate, owing to the cul-de-sac (Z) layout of the dam and a large eddy circulating near the entrance) had high performance levels that were attributed to good entrance locations.

- Entrances at Fish Concentration Points Created by Guidance Devices – A behavioral guidance structure has been attributed in Lower Granite Dam's surface passage studies to direct fish away from powerhouse units and to make more fish available for possible passage through SFO entrances.

Multiple Entrances - One means to increase discovery of an SFO is to provide multiple entrances, but SFO discharge amounts as well as site specific features will determine benefits. Multiple entrances are a common feature of powerhouse retrofit SFOs. For example, at Wells Dam, high SFO performance has been influenced by multiple entrances located across the width of the dam and therefore maximizing exposure potential. However, it should be noted that in some situations (e.g., Lower Granite surface passage work), there are advantages to concentrate more flow into fewer entrances versus more entrances with lesser flow per entrance in order to gain greater forebay fish attraction at locations where fish are known to accumulate.

<u>Decision Zone Features</u>

There are many features that affect fish behavior in the Decision Zone, including entrance configuration and orientation, local competing flows in the near-field (e.g., turbine and spill), turbine intake occlusion, SFO flow rates, velocities, accelerations, etc. However, fish behavioral responses to particular features are not well understood, the data are inconclusive, or the feature may be common to most SFOs. Nevertheless, we identified a set of key SFO entrance features in the Decision Zone that in our assessment influence biological performance.

SFO Q Fraction - The greater the SFO proportion of the total flow passing a project, the more prominent the SFO flow net in the forebay and, accordingly, the greater the probability of smolts detecting the entrance. This characteristic also acts as an indirect indicator of entrance area, since larger (or more) entrances typically pass larger flows.

Invert Depth - A simple strategy to increase the discovery and entry into an SFO is to intercept a greater portion of the deeper traveling smolts. This can be accomplished by deepening the floor at the entrance to the SFO. However, it should be noted that for a fixed entrance discharge, there may be some trade-off in terms of horizontal influence of the SFO flow net.

SFO Q - For years it has been held that since Wells is very efficient, many of its characteristics should be incorporated into the design of new SFOs. Since each Wells entrance discharges about 2 kcfs, this has become an unofficial minimum standard for larger projects. This feature complements, but is distinct from the Q fraction described previously.

Smooth Acceleration – Fish acceptance of an SFO entrance may be influenced by whether the flow approaching the entrance and/or capture location continues to accelerate smoothly, or if the acceleration is abrupt, or even inconsistent with areas of deceleration.

Width at Capture – Another important characteristic is whether capture velocity is achieved in an area where the dimension of the SFO is large or small. A small dimension may result in a larger fraction of the flow cross section being influenced by a fluid strain signature above a critical threshold value detectable by and causing a rejection reaction by fish. A small dimension may result in a sense of confinement by fish. If capture is achieved where the SFO dimension is larger, rejection of the SFO will be less likely.

Entrance Velocity - We reason that if the water velocity at the entrance exceeds some critical value fish will be effectively trapped and incapable of avoiding entrainment.

<u>Reference Points</u>

We constructed a matrix (Table 4-4) that identified the presence (✓) or absence (blank) of the Discovery and Decision zone features associated with our set of SFOs. Numerical reference points in this table (i.e., greater than or less than specific values) was provided to highlight relative differences between projects. We do not purport that the reference points represent design criteria. The following reference points pertain to features in the Decision Zone.

SFO Q Fraction > 5% - We adopt 5% of powerhouse capacity as a reference point to generally delineate large from low flow SFOs. This reference point is based on the Wells Dam SFO, which passes 5-10% of the river discharge.

Invert Depth (> 10 ft) - Among our set of SFOs we distinguish between two general classes with respect to entrance depth: the shallow skimming-type represented by sluiceways, and the deeper entrances characteristic of surface spills, forebay collectors, and powerhouse retrofits. Often times these inverts are much deeper than the 10-ft breakpoint we use to delineate between deep and shallow.

SFO Q > 2 kcfs - The 2 kcfs reference point, as mentioned above, is founded on the operating condition at Wells Dam, the original powerhouse-retrofit SFO.

Smooth Acceleration ($A < 3 ft/sec^2$) – The 3 ft/sec^2 reference point is placed at a breaking point in the data between entrances specifically developed to provide smooth acceleration, i.e., the surface spills and those with abrupt accelerations and higher flows intended to push capture location to the plane of the entrance and upstream. Failure to provide a consistently increasing acceleration, with zones of deceleration would cause an SFO to not be considered to have smooth acceleration, even through the acceleration magnitudes fell below the 3 ft/sec^2 reference value. SFO entrances for which no hydraulic profile data are available (see Table 4-1) were still classified under this characteristic by being grouped with entrances of similar geometry and flow rate and which therefore should deliver a similar acceleration profile.

Width at Capture > 20 ft – A reference point of 20 ft was selected, which split the SFOs studied into two groups of roughly equal number.

Entrance Velocity > 7 fps - We adopted 7 fps as a generic trapping velocity for smolts based on Bell (1991). Thus in Table 4-4, SFO entrances with an entrance velocity > 7 fps reference point were designated with a check mark.

Table 4-4. Presence (✓) or absence (blank) of key SFO features

(Note: Greater than or less than values associated with feature descriptions are provided as reference points to highlight relative differences between projects; they do not represent design criteria).

				Discovery Zone				Decision Zone					
				Vertical Distribution		Horizontal Distribution		Entrance Conditions					
Project	SFO Type	Spring Bio-Index	Summer Bio-Index	Sill or Shallowing Forebay	No Competing Far-Field Flow	Optimal Location	Multiple Entrances	SFO Q Fraction > 5%	Invert Depth >10 ft	SFO Q (>2 kcfs/ent)	Acceleration < 3 ft/s^2	Capture Width >20 ft	Entrance V > 7 fps
Bonneville 1st	Retrofit PSC	0.44	---	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Bonneville 1st	Sluiceway	0.46	0.52	✓	✓	✓	✓				✓	✓	
Bonneville 2nd	Sluiceway Corn.ner Coll.ector	0.45	0.40	✓		✓			✓	✓			✓
Cowlitz Falls	Retrofit	0.33	---	✓	✓	✓	✓		✓		✓		
Ice Harbor	Sluiceway	0.32	---				✓	✓			✓		✓
Ice Harbor	Surface Spill RSW	0.37	0.51			✓		✓	✓	✓	✓	✓	✓
Lower Granite	Retrofit SBC	0.32	---			✓			✓	✓			✓
Lower Granite	Surface Spill RSW	0.49	0.44			✓		✓	✓	✓	✓	✓	✓
Priest Rapids	Sluiceway	0.03	0.04								✓	✓	✓
Rocky Reach	Forebay Corner Collector	0.45	0.25			✓			✓	✓	✓		
The Dalles	Sluiceway	0.11	0.07	✓		✓	✓				✓	✓	
Wanapum	Retrofit	0.003	0.003						✓		✓		
Wanapum	Sluiceway	0.05	0.06								✓	✓	✓
Wanapum	Surface Spill	0.17	---						✓	✓		✓	✓
Wells	Retrofit	0.89	0.89	✓	✓	✓	✓	✓	✓	✓	✓	✓	

4.5 SFO Summaries

Information used to develop these SFO summaries was taken from Tables 4-1 to 4-4, the synopses in Chapter 3 and the master hydraulic matrix in Appendix B. In this section, we identify key aspects of each SFO that in our assessment either contribute to or impede collection efficiency performance at that site; conveyance and outfall features are not included in this material. We organized this section by SFO type, as defined in Chapter 2 of this report.

Forebay Collector

Rocky Reach -- Discovery zone features at this dam foster high SFO passage rates. The Z-dam layout assists in corralling fish at the terminus of the forebay where the SFO is situated. Additionally, a large eddy concentrates and re-circulates fish in the corner near the SFO entrance. In combination these features are advantageous in increasing encounter rates by directing smolts toward the SFO entrance. The entrance conditions, generally modeled after Wells, provide a double channeled deep invert with velocity and inflow of the same general magnitude as Wells. Collectively the SFO is quite efficient relative to other sites and the set of features in both the Discovery and Decision Zones contribute to an efficient system.

Retrofits

Wells Dam -- At this site the presence of a shallow sill on the approach path to the dam coupled with the hydrocombine layout serve to concentrate smolts both vertically and horizontally upon arrival at the dam. In combination with five SFO entrances that span the entire dam, the encounter probability with an SFO entrance is maximized. The high smolt FCE (about 89%) measured at this site indicates that the collective features in the Decision Zone foster good entrance efficiency. Thus, the modest entrance velocity (2 fps) and intake discharge (2 kcfs/entrance), gradual acceleration gradient upstream from the entrance, and ample entrance area do not discourage and may well encourage smolt acceptance of this passage route. Importantly, the deep invert (72 ft) ensures any deep migrating smolts also have a high probability of encountering an SFO entrance rather than the turbine intakes immediately below the entrances. We reason that the substantial competing turbine-flow net in the near field does not substantively diminish SFO passage. Collectively, features in the Discovery and Decision zones work in concert to formulate the most efficient and effective SFO we studied.

Cowlitz Falls -- In sharp contrast, the hydrocombine on the Cowlitz River exhibits poor smolt passage efficiency, even though it shares some of the features present at Wells Dam, which we consider to be favorable. Features in the Discovery Zone encourage high encounter probability. The narrowing forebay and presence of a coffer dam remnant on the approach path concentrate fish vertically and horizontally, as evidenced by relatively high proportions of tagged smolts detected near the entrance. However, features in the Decision Zone and dewatering system promote rejection of the SFO. In our assessment, several deficiencies appear to contribute to the high entrance rejection rate: complex and turbulent near surface hydraulic conditions associated with the debris barrier; weak entrance velocity (0.6 fps); and a negligible and inconsistent acceleration gradient within the screened channel, coupled with a constricting and confining cross-sectional area (down to 2 ft x 2 ft) upstream from trapping velocity location. We conclude that the combined effects of these conditions cause a high proportion of smolts to reject collection at the Cowlitz Falls surface flow outlet.

Lower Granite SBC -- A variety of partial powerhouse SFO configurations were tested at the Lower Granite SBC over 1996-2000. The final and best performing configuration that we profile here was tested in 2000 with a 16 ft wide X 28 ft deep entrance and the simulated Wells intake (SWI) present. The presence of a BGS provided a mechanism to concentrate and direct fish near the entrance. However, spill discharge created far field flows that competed with this strategy. On balance, features in the Discovery Zone created competing conditions that were not wholly advantageous. In the Decision Zone, high entrance velocity (7.8 fps), substantial flow (3.5 kcfs), abrupt acceleration, and a moderately deep intake produced acceptable entrance efficiency estimates (42-84%). The SWI appears to have enhanced entrance efficiency by spatially separating the SBC from turbine intake flow. We found that, while the full potential of the SBC, a powerhouse retrofit SFO, was not realized because of competing passage strategies (e.g., voluntary spill), lessons learned from SBC tests were useful to design the RSW, a surface spill SFO.

Bonneville 1 PSC -- A shallowing forebay concentrated fish vertically, and the configuration of the powerhouse concentrated them in the forebay in the vicinity of the multi-entrance PSC that spanned Units 1-6 out of the ten units at the B1 powerhouse. In general terms, these Discovery Zone features paralleled those that are deemed to be beneficial at Wells Dam. The PSC was one of the top performers based on the bio-index score (0.44). If this partial powerhouse prototype SFO had extended across the entire B1 powerhouse, then FCE would have been even higher.

Wanapum SAC -- In the Discovery Zone there were no obvious natural or manmade features to concentrate fish either vertically or horizontally. This constituted a deficiency with respect to maximizing encounter efficiency. In the near-field Decision Zone, some SFO features resembled the Wells condition. Entrance velocity was moderate (near 2 fps), and the invert extended to considerable depth (50'). But other features differed from the Wells model- only 1-2 entrances were provided with total volume well below our 5% powerhouse capacity reference point. Performance of this structure was the poorest in our suite of SFOs, with a fish collection efficiency bio-index of < 1%. We deduce that the absence of concentrating mechanisms (horizontally and vertically) or a natural congregation zone for smolts greatly reduced the probability of smolts encountering the SFO resulting in very low FCE.

<u>Sluiceways</u>

With respect to sluiceways as a class of SFO, we note the following considerations. First, none of the sluiceways, except B2 Corner Collector, was designed for fish passage. Second, in general there are two configurations, shallow skimmers and chutes that draw from a deeper range of the water column. Third, early observations at existing sluiceways indicated that they pass fish effectively, which spawned SFO development in the region. And, fourth, these passage routes continue to be useful non-turbine routes and the subject of further SFO development.

B1 Sluiceway -- At the B1 sluiceway, fish are concentrated vertically and horizontally due to the relatively shallow, confined forebay and lack of far-field competing flows. Multiple SFO entrances provide multiple passage opportunities for juvenile salmonids. Skimming flow (1,500 cfs total) into the six entrances, each 21 ft wide and 7 ft deep, has moderate velocity (< 7 fps) and acceleration (< 3 ft/s2). The B1 sluiceway is an efficient (FCE 48%) and effective (FCF 15) non-turbine passage route at B1 that will continue to be routinely operated to protect smolts passing the project. Future improvements could include new entrance, conveyance, and outfall structures.

B2 Sluice Corner Collector -- The B2 sluice corner collector takes advantage of a shallow forebay and a prominent eddy that collectively serve to concentrate fish vertically and horizontally at the southern corner of the powerhouse where the SFO is located. The circulating eddy is typical during most B2 powerhouse unit loading patterns. It provides multiple opportunities for fish to discover the SFO flow net. In the Decision Zone, the large entrance flows (~5,300 cfs) entrain fish in the vicinity (~25 ft) of the weir at this single large (15 ft wide X 22 ft deep) entrance. While competing flows, which produce a second eddy at the northern part of the powerhouse, pass at least half of the downstream migrants, many of these fish are diverted from turbine passage by intake screens. The B2 sluice corner collector has a custom design conveyance channel and outfall to pass fish safely past the dam into the tailrace below Cascades Island. Fish passing through the B2 sluice have the highest survival rates (100%) of all routes at the Bonneville Dam complex. Beneficial features in the Discovery, Decision, Conveyance, and Outfall Zones act in concert to produce an efficient and safe SFO.

Ice Harbor Sluiceway -- Other than the natural, surface-oriented distribution of juvenile salmonids, the Ice Harbor sluiceway SFO did not have physical features that enhanced vertical and horizontal concentration of fish at the sluiceway entrance weirs. Multiple entrances, however, increased the probability of encounter. Entrance velocities appeared to achieve capture. Overall, fish collection efficiency in spring was 32%. FCE was likely negatively influenced by involuntary spill flows. Concerns about adverse effects on fish passage during conveyance, outfall, and egress led managers to replace the sluiceway with turbine intake screens and a spill program to provide safe passage for smolts. The Ice Harbor sluiceway, however, demonstrated the validity of the SFO concept.

Priest Rapids Sluiceway -- At Priest Rapids Dam, there are no features that concentrate fish vertically or horizontally, nor did we observe any indication that the sluiceway was situated in a location where fish naturally congregate or migrate. We consider these to be severely limiting factors contributing to very low FCE (5%), given experiences at other sites. Furthermore, the single shallow entrance with low inflow but high velocity collectively offered little advantage for collecting smolts. The paucity of features in both the Discovery and Decision Zones (Table 4-4) plausibly explains the inefficiency of this SFO.

The Dalles Sluiceway -- The Dalles sluiceway has a shallow forebay that helps to concentrate fish vertically. Furthermore, the powerhouse itself serves as a guidance structure as fish migrate down the face of the dam from east to west. However, spillway discharge, recently as high as 40% of total river discharge, creates far-field competing flows that suppress project-wide FCE values (7-11%) for the sluiceway SFO. Locating three sluiceway entrance gates at the west end of the powerhouse and three more at intermediate places along the dam provide multiple SFO portals. Entrance inflow decreases (~1,000 to 600 cfs per entrance) as distance increases from the hydraulic control point at the west end of the sluiceway channel (total discharge 4,500 cfs). Generally, the skimming flow into a given sluice entrance (20 ft wide and 8 ft deep) has gradual acceleration (< 3 ft/s2). The Dalles Dam sluiceway is an effective smolt protection measure for the project that may be enhanced in future SFO developments at the dam. Its overall contribution to smolt passage is diluted by the current high spill passage strategy.

Wanapum Sluiceway -- The Wanapum sluiceway has no prominent physical or hydraulic features in the Discovery Zone to concentrate fish horizontally or vertically. The opportunity for discovery depends on the surface-oriented vertical distribution and fish migration pathways along the face of the dam. Nonetheless, this sluiceway with a single entrance 20 ft wide and 9 ft deep has fish collection efficiencies of 6-7% using 2,000 cfs, which is 2% of powerhouse hydraulic capacity. The Wanapum sluiceway is another example of a sluiceway SFO that is effective at passing fish for the amount of water it uses, but is not sufficient as a stand-alone, non-turbine passage route for the project as a whole.

Surface Spills

Lower Granite RSW -- This surface spill SFO is located at the powerhouse end of the spillway in the old river channel thalweg where there is not a sill or shallowing in the bathymetry, but this is a known migration pathway for fish. A log-boom and BGS enhance fish movement toward the RSW. In the Decision Zone, the RSW entrance was designed with shaping that promoted a gradual acceleration of flow to trapping velocity and critical depth over a weir crest very near the entrance where the dimensions of the flow cross section were reasonably large (26 ft deep by 48 ft wide). Consequently, flow through this surface spill SFO is relatively large (~6,000 to 12,000 cfs). High entrance efficiencies (0.92 to 0.94) indicate fish very readily accept and pass this SFO. High fish collection efficiency (49%) demonstrates the success of this SFO.

Ice Harbor RSW -- Similar to Lower Granite, the Ice Harbor surface spill SFO does not have features that vertically concentrate fish. Furthermore, there are no natural physical or hydraulic features that concentrate fish horizontally. By design, the RSW was placed near the powerhouse end of the spillway in the thalweg where fish are known to migrate. Under current dam operations, pronounced spillway discharge competes with the RSW flow net, thereby diminishing the SFO's overall effect in the forebay. In the Decision Zone, the features are similar to those at the Lower Granite surface spill SFO. The RSW discharges a relatively large amount of flow (7,500-10,500 cfs) creating a prominent flow net, gradual flow acceleration, and high entrance velocities. Although FCE at the Ice Harbor RSW was moderate (37%), it could possibly have been higher if there was less spill. The design of the Ice Harbor RSW, compared to Lower Granite, hydraulically smoothed the transition from the RSW to the spillway ogee to reduce the formation of shockwaves, a potential area of concern for fish injury.

Wanapum Surface Spill -- The Wanapum surface spill prototype was located at Bay 12 at the end of the spillway adjacent to the future units non-overflow section of the dam and was used as a stage in development of the Future Units Fish Bypass (FUFB), which is presently under construction. In this location there are no hydraulic features known to concentrate fish, but the Z-dam geometry makes the physical downstream-most point of potential fish migration. The geometric location was confounded by powerhouse flows competing with the SFO flow in the Discovery Zone and by spill competing in the Decision zone, reducing the SFOs overall effect in the forebay. In its initial test configuration of a slotted bulkhead emulating Wells-type slots, the FCE was low (17%). In further development the bulkhead was converted to an 11,000 cfs and then 20,000 cfs top spill configuration to determine if increased flow and a configuration that provided a more abrupt acceleration to trapping velocity actually in front of the SFO entrance in the forebay would be effective at fish collection. This resulted in an increase in FCE to over 25% and an entrance efficiency compared to a Discovery Zone limit of 300 ft from the entrance, of 86%, These results were considered adequate proof of concept for advancing the FUFB design, but with a location adjacent to the powerhouse end of the future units where powerhouse flow would enhance discovery by delivering fish adjacent to, rather than competing with the SFO.

5.0 Discussion and Recommendations

In this chapter, we present overarching themes and suggest design considerations that address important issues regarding SFO performance and lessons to bear in mind when refining existing or designing new systems. We also identify several areas where basic research would improve understanding of SFO performance and their design. Finally, we offer recommendations pertaining to a process model for SFO development and identify next steps, such as how this compendium can be used and updated as new information accumulates.

5.1 Overarching Themes

This section contains important, “big picture” conclusions and themes distilled from the collective information.

SFO type is not a primary factor affecting fish collection efficiency. Indeed all four SFO types (retrofit, sluice, surface spill, and forebay collector) are represented in the top eight performers (Table 4-4). Of more importance may be characteristics concerning SFO location, fish concentration, and entrance conditions.

In general, the SFOs with high bio-index values tend to have more of the features that we suggest contribute to high collection efficiency. This suggests that design teams should consider at least the breadth of the ten SFO features discussed in Section 4.4 and listed in Table 4-4 when formulating SFO designs and placement of entrances. Furthermore, we generally observed that good entrance conditions cannot override the need for features that contribute to vertical and horizontal concentration of smolts or locating entrances in locales where smolts naturally congregate. This is evidenced by the observation that the four SFOs with the lowest bio-index scores lacked beneficial Discovery Zone features.

Smolts generally follow the bulk flow patterns as they approach a project. We make this statement by inference from observations regarding competing flow nets and eddy-lateral current flows. This is an important element in our conceptual framework, which in our view is supported in this review of regional SFO systems.

Location of the SFO entrance(s) relative to smolt pathways and concentration areas in the forebay is a primary consideration for maximizing FCE. Both vertical and horizontal distribution of smolts is important in this regard. Natural features like sills and shallowing forebays are beneficial in that they shift the population up toward the SFO (e.g., Wells retrofit, B2 sluiceway corner collector). In turn, extending the depth of the invert can increase the probability of encounter (e.g., B1 retrofit PSC). In the horizontal plane, natural features like cul-de-sacs, lateral currents, or eddies can direct smolts toward an SFO (e.g., Rocky Reach forebay collector, B2). Absent these features, physical guidance devices can serve to direct fish horizontally toward an SFO (e.g., the BGS and trash boom at Lower Granite Dam).

A particular dam configuration does not create conditions that guarantee success. For example, the Wells Dam (hydrocombine) SFO performed well, whereas at the Cowlitz hydrocombine, the SFO facility did not. Both projects are configured as hydrocombines and have features that foster horizontal and vertical concentration. However, poor conditions of velocity gradient downstream from the entrance and before capture at Cowlitz may have negated those benefits. In addition there is a difference of configuration downstream from the entrances and a difference in scale between Wells and Cowlitz. Competing broad scale flow nets from different passage routes influence SFO performance to varying degrees. For example, collection efficiency at The Dalles Dam sluiceway and the Lower Granite retrofit SBC were significantly reduced by the far-field spillway flow net.

SFO fish collection efficiency of subyearling Chinook salmon during the summer rivaled that of yearling Chinook in the spring. Fewer studies have examined summer migrants. But, generally at sites where these studies have been implemented, performance (bio-index) for spring and summer fish was similar (Table 4-1). The exception was at Rocky Reach, for which only one year of questionable data for subyearlings was available.

Species matter. The optimum SFO design is species dependent. There is some evidence that certain SFO types may be less effective for certain species, e.g. sockeye and Chinook at the Rocky Reach Corner Collector SFO.

Safe conveyance and outfall conditions must be attended to. SFOs must be designed holistically from forebay to tailrace.

5.2 Design Considerations

In the following we present SFO design considerations derived from our review of the material presented in the rest of this report. We have organized our design considerations according to the SFO zones presented in our conceptual framework in Chapter 2.

Approach and Discovery -- Fish follow the bulk flow patterns as they approach a project. At sites where the bulk flow splits in different directions, the smolt population splits too, in some cases diminishing encounter with the SFO entrance location. This leads to several guidelines relative to project layout and SFO placement:

- Put the entrance where the fish are concentrated. SFO placement at linear dams is best in a location where the bulk flow to the dam delivers fish to proximity of the SFO (e.g., the surface spill SFO at Ice Harbor Dam).

- SFO placement at Z-dams, with the powerhouse axis parallel to the river, is best within the cul-de-sac near the downstream end of the powerhouse, where the downstream most migration point is reached, an eddy is formed, and the entrance should be located along the periphery of the eddy (e.g., the forebay collector at Rocky Reach Dam).

- At projects where there are no layout or flow field features available to concentrate fish, something must be done to horizontally concentrate fish or provide multiple entrances. Either a significant SFO flow or a forebay guidance device may be required to aid discovery of the SFO flow net (e.g. the RSW and BGS at Lower Granite Dam. Alternatively, placing the SFO in known migratory pathways may maximize probability of SFO discovery and affording smolts access to a surface outlet.

- Careful consideration of turbine priorities and spillway operations during SFO design, evaluation, and long-term implementation is important because operating priorities can affect bulk flow patterns, which in turn affect fish passage patterns.

Decision -- Juvenile salmonids will readily pass into a surface flow outlet if the entrance conditions are “right.” Although exact physical and hydraulic specifications for what is “right” are not precisely known, we offer these points for consideration:

- For SFOs having critical flow regime entrances (e.g., various RSWs and the corner collector at Bonneville 2nd Powerhouse), entrance efficiency is enhanced by achieving near capture velocity at the entrance plane of the SFO. Based on our review, we hypothesize that maximizing the entrance area and the velocity at the flow control location downstream from the SFO entrance plane enhances passage at these SFOs.

- Flow deceleration should be avoided at any location upstream from capture (e.g., the prototype SFO at Rocky Reach Dam).

- Rapid acceleration within a confined SFO structure, but before capture, should also be avoided. We infer this consideration from anecdotal data from the Cowlitz Falls project. The velocity profiles, and acceleration and gradient profiles for the Cowlitz SFO, are similar to those at successful surface spill type projects near the capture velocity location. However, fish reject and back out of the Cowlitz screens near the capture location. The difference is that increasing velocity occurs inside the structure, where distances to flow boundaries are much smaller. It is better to achieve capture near the SFO entrance. However, there probably is a threshold acceleration that should not be exceeded even in the unconfined approach to an SFO entrance.

- SFO designs must be holistic. For example, the hydraulic design characteristics of the Wells Dam retrofit SFO are not always applicable to other projects. The region focused on entrance conditions (e.g., 2-fps mean entrance velocity at vertical slots). However, developers did not consider the interaction of all components. The Wells SFO is a success because vertical, horizontal, and entrance conditions are optimal.

Conveyance and Outfall -- The primary purpose of the conveyance and outfall structures is safe passage from the forebay to the tailrace. To this end, we make the following suggestions:

- High flow dewatering for fish is possible and should be considered if necessary. The Rocky Reach SFO dewaters 6,000-cfs entrance inflow down to 240-cfs SFO bypass flow.

- High flow outfall guidelines (PNNL et. al. 2001) are applicable for design of conveyance and outfall structures.

5.3 Research Needs

Our review revealed several important deficiencies in the knowledge base for regional SFOs. Research addressing these topics would be useful to future SFO development efforts.

Estimates of discovery efficiency and entrance efficiency using standard methods are sparse. Our bio-index based on FCE reflects SFO performance over a broad spatial scale, extending from approach to the forebay through collection in the SFO. This coarse index does not permit a focused fine-scale evaluation of the mechanisms individually contributing to FCE. We sought consistent estimates of discovery and entrance efficiency to aid in that endeavor, but found a paucity of information. We encourage the Corps and others to require such estimates to be obtained and reported in its research studies. Miniaturized radio or acoustic tags offer means to obtain such estimates. Standardized protocols would be advantageous for the region, but none now exist. We suggest this effort be pursued in a workshop setting. Future SFO evaluations should include estimates of discovery and entrance efficiencies along with FCE.

The relationship between hydraulic and other physical conditions and fish responses in the Decision Zone within about 30 ft of SFOs is uncertain. Basic empirical data on fish response to SFO flow fields has been collected previously, but most of the studies had issues with synchronizing the fish and water data sets. Future research should address the synchronicity issue and examine empirical relationships between fish movements and flow conditions. Additional work on understanding the relationship between fish response and hydraulic and other physical conditions might be performed in a laboratory setting where stimulus conditions can be rigorously controlled.

The need for gradual shaping, i.e., acceleration criteria, at an SFO entrance is not well established. That is, how important is entrance shaping to successful passage? For example, a statistically rigorous experiment using a removable shaped entrance at an existing sluiceway (e.g., the portable sluiceway weir tests idea for

The Dalles Dam; Johnson et al. 2007) could be used to address this uncertainty. The treatments could be with and without shaping. The response variable would be passage rate into the sluice entrance. Research is also needed to determine whether flow rates can override the relative contribution of SFO flow boundaries to the hydraulic strain signature that may cause fish reaction and avoidance.

SFOs may benefit other life history stages and less abundant species, but we do not have much data on these fish. For example, during fall and early winter, steelhead kelts migrate downstream through the hydrosystem. These fish could benefit from SFOs as a passage route instead of turbines. In addition, while steelhead and Chinook salmon are the object of much research at Corps dams, other salmonids such as sockeye and coho salmon should also be considered.

Research on the effect of turbine intake occlusion on SFO performance has been mixed depending on the site. Turbine intake occlusion may be beneficial at sites where there is little separation between a relatively shallow turbine intake and the SFO entrance, whereas there is no benefit of occlusion where the turbine intakes are deep relative to the SFO entrance invert. The transition point is ill defined.

Research on near field project operations adjacent to an SFO. The trade-offs between providing training flow adjacent to an SFO to promote safe tailrace egress of juvenile fish versus the negative impact of competing near-field flows in the forebay on SFO FCE are ill-defined.

Indirect and sub-lethal effects on juvenile salmonids from passage through the Conveyance and Outfall Zones are not well-understood. In addition to direct and total survival estimates, development of SFOs must also be cognizant of the other potentially deleterious effects on fish from SFO passage. Inour opinion, more research is need on this matter.

5.4 Development Process Model

The SFO development process model involves three phases: Preparation, Prototype, and Production. These phases are necessarily sequential. However, within each phase there is considerable feedback and adaptive management. The scope of work within a given phase will vary depending on the SFO and the site. Lessons learned from the synopses (Chapter 3), the workshop (Appendix A), and project descriptions (Appendix C) lead to the following recommendations for steps to develop a full production SFO.

Preparation -- The preparation phase starts with initiation of the development process and ends with a conceptual design for a prototype of the preferred alternative. Suggested preparation steps are:

- Set-up a project development team consisting of owner, resource agency, and expert representatives.
- Establish realistic route-specific survival and fish collection efficiency goals by species.
- Thoroughly consider all authorized uses of the project and how an SFO might impact them and v.v.
- Describe baseline biology including species of interest, migration pathways, forebay residence times, tailrace egress rates, and diel, horizontal, and vertical distributions in the forebay and during passage at the dam.
- Convene a brainstorming workshop to develop a list of SFO alternatives.
- Develop a decision matrix for alternatives based on SFO type and flow and assessment of probable performance, economics, and other considerations.
- Develop a CFD and/or physical model(s) of the project (forebay and tailrace). Use these models to investigate alternatives and the effects of geometric arrangements and flows on flow conditions in the

Decision Zone as compared to best of class hydraulic criteria. Investigation is best pursued through a combination of expert judgment, statistical analyses, and, when appropriate, behavioral modeling such as through the Numerical Fish Surrogate (Goodwin et. al. 2004).

- Reach a decision on the prototype SFO and the monitoring and evaluation plan. Communicate and explain this decision to all interested parties.

- Develop a conceptual design for a prototype of the preferred alternative

Prototype -- The prototype phase begins with by developing the detailed design of the prototype SFO and concludes with a decision and conceptual design for the full production system. Suggested prototype steps are:

- Design, procure, and install the prototype SFO. Use the model/s to investigate various SFO entrance and outfall locations and flows and ascertain the opportunity for discovery by defining congruency of approach flow net with migration pathways and safe egress away from areas that are known to be or may become predator habitat as a result of eddying flow patterns.

- Perform detailed biological and hydraulic measurements and modeling. Based on the results, modify the design as necessary and retest.

- Continue outreach with all interested parties.

- Reach a decision on the prototype SFO and the monitoring and evaluation plan.

- Develop a conceptual design for a prototype of the preferred alternative

Production -- The production phase starts with the production concept and finishes with a fish-friendly SFO ready for routine operation and accepted by the owner/operators and the resource agencies. Suggested steps are:

- Design, procure, and install the production SFO.

- Perform biological and hydraulic studies over three years to confirm that the SFO performance goals are being met.

5.5 Next Steps

In preparing this compendium, we considered the Strain-Velocity-Pressure (SVP) hypothesis of fish movement that has been proposed by Goodwin et al. (2006a; 2006b). We found meshing the SVP hypothesis with the conceptual framework that we developed was not achievable without extensive interaction with the researchers who have developed the hypothesis. We recommend a meeting be held with the SVP hypothesis researchers to further examine the application of the SVP hypothesis to our conceptual framework. The product of this meeting could be used in a future update of this compendium.

In the next 2 to 5 years, many SFOs will be deployed at the dams studied in this compendium. These efforts will provide new information to refine the SFO premises and analyses. We recommend that the Corps and others update the compendium periodically every three to four years; convene bi-annual SFO workshops to share information throughout the region and use this information to update the compendium; make the SFO Compendium available electronically on a Corps website; and, establish and maintain an electronic library of SFO-related publications plus design and evaluation reports. The September 2006 workshop might be considered the initial kick-off workshop for this series. Future workshops should include general review topics as well as a focus area or two, such as one of the basic research needs.

List of Acronyms

ADCP	Acoustic Doppler Current Profiler
ADV	Acoustic Doppler Velocimeter
BGS	Behavioral Guidance Structure
BiOp	Biological opinion
CC	Corner Collector
CFD	Computational fluid dynamic
DE	Discovery Efficiency
EE	Entrance Efficiency
FCE	Fish Collection Efficiency
FCF	Fish Collection Effectiveness
FCS	Flow Control Structure
FERC	Federal Energy Regulatory Commission
FPTWG	Fish Passage Technical Working Group
FSC	Floating Surface Collector
FUFB	Future Unit Fish Bypass
NMFS	National Marine Fisheries Service
NTS	Net Transition Structure
PGE	Portland General Electric
PH	Powerhouse
PMF	Probable Maximum Flood
PSC	Prototype Surface Collector
PSE	Puget Sound Energy
PUD	Public Utility District
RSW	Removable Spillway Weir
SAC	Surface Attraction Channel
SBC	Surface Bypass and Collector
SFO	Surface Flow Outlet
SWI	Simulated Wells Intake
SWW	Selective Water Withdrawal
TDG	Total Dissolved Gas
TSW	Temporary Spillway Weir

List of SFO Terminology

Approach Zone – Upstream extent of forebay where juvenile salmonids first encounter the effects of dam.

Behavioral Guidance Structure (BGS) – A structure used to concentrate fish in the vicinity of and SFO entrance.

Conveyance Structure – Conveys water and fish between the entrance structure and outfall.

Critical Flow – When water moves downstream as fast as a wave can propagate upstream.

Decision Zone – Area upstream from SFO where juvenile salmonids choose to enter or reject entrance.

Dewatering Device – Screens or louvers used to reduce the amount of flow necessary to pass fish.

Direct Survival – Smolt survival through the main components of the SFO (entrance, conveyance and outfall).

Discovery Efficiency (DE) – The proportion of smolts passing the dam that arrives near the entrance to the SFO.

Discovery Zone – Where juvenile salmonids first encounter an SFO flow net in the forebay.

Entrance Efficiency (EE) – The proportion of fish near the SFO entrance that enter and pass through the SFO route to the tailrace.

Entrance Structure – Upstream-most projection of the SFO where fish and flow enter.

Fish Collection Efficiency (FCE) – The proportion of smolts passing the dam that does so via the SFO.

Fish Collection Effectiveness (FCF) – The ratio of FCE to the proportion of total project discharge through the SFO during a given FCE study.

Flow Net – The region within which flow accelerates to enter the SFO.

Flow Regime – The hydrodynamic flow state defined by whether a wave propagates up or downstream.

Forebay Collector – Structure in the forebay designed to extract fish for conveyance downstream past dam.

High Flow Sluice – 1240-5300 cfs capacity surface water outlet originally designed to manage ice/debris.

Low Flow Bypass/Sluice – ≤ 530 cfs capacity surface water outlet at dam with relatively small discharge.

Outfall – Structure discharging flow and fish into the tailwater downstream from the dam.

Powerhouse Retrofit – SFO structure built onto the forebay face of a powerhouse.

Removable Spillway Weir – SFO utilizing an uncontrolled weir bypass retrofit in a spillway bay.

Surface Flow Outlet – An SFO is a surface-oriented fish collection and bypass system for a dam.

Subcritical Flow – When water moves downstream slower than a wave can propagate upstream.

Supercritical Flow – When water moves downstream faster than a wave can propagate upstream.

Surface Spill – Surface flow outlets at spillways using RSW, flap gates, bulkheads, etc. to produce top spill.

Total Survival – Smolt survival through the SFO and some portion of the tailrace.

Appendix A

Workshop Notes

Surface Flow Outlet Workshop

September 6-7, 2006

Portland, Oregon

The Portland and Walla Walla Districts of the U.S. Army Corps of Engineers (the Corps) are sponsoring the preparation of a comprehensive review report regarding the development of surface flow outlets (also called surface bypasses) to pass downstream migrant juvenile salmonids at hydroelectric dams in the Pacific Northwest. The information on facility development at both federal and non-federal dams is scattered in dozens of engineering and biological reports published by different agencies that, in many cases, are not part of the public literature. The objective of this report is to develop a single reference documenting surface bypass development in the region that provides general design and operational considerations to guide biologists and engineers in future surface bypass development.

The Corps hosted a two day workshop on surface flow outlets in September 2006 in Portland, Oregon. Prior to the workshop, we complied a database of approximately 450 references that are relevant to the comprehensive surface bypass review report and annotated over 45% of these references. The information obtained from the presentations and discussions during the workshop supplemented the surface flow outlet reference database and is being incorporated into the comprehensive review report.

The agenda for the two-day workshop is presented in Tables 1 and 2, for September 6th and 7th respectively. On the first day and a half of the workshop presenters gave brief (25 minute) presentations followed by short question and answer (5 minute) sessions on the development of surface bypass systems at their respective projects. The presentations described surface bypass development at key facilities, identifying not only the chronology, facility features, and biological success, but also the process of data collection, modeling, prototype testing, and key decision-making that led to the present facility configuration. The information provided by these presentations was incorporated into the project descriptions and is included in Appendix B.

The presentations were followed by a forum discussion of the overarching themes identified in the presentations, which included information gaps, necessary components or steps, and lessons learned. Overarching themes identified in the round table discussion will be incorporated into the synthesis and discussion section of the report. The minutes from the round table discussion are presented in the following section. In addition, a list of workshop attendees is included as Table 3.

Table 1. Day 1 Workshop Agenda, September 6, 2006

Time	Topic	Presenter
8:30	Welcome	Randy Lee
8:45	Introduction	Chick Sweeney
9:15	Douglas County PUD Overview: Wells	Rick Klinge
9:45	Break	
10:00	Chelan County PUD Overview: Rocky Reach and Rock Island	Chuck Peven
11:00	Grant County PUD Overview: Wanapum and Priest Rapids	Curt Dotson & Dana Jeske
12:00	Lunch (on your own)	
13:00	Walla Walla District Overview	Lynn Reese
13:15	Lower Granite	Lynn Reese
13:45	Ice Harbor	Lynn Reese
14:15	Lower Monumental	Ken Hansen
14:30	Little Goose	Sean Milligan
14:45	McNary	Dan Feil
15:00	Break	

Time	Topic	Presenter
15:30	Tacoma Power Overview: Mayfield and Cowlitz Falls	Mark LaRiviere & Steve Fischer
16:30	Upper Baker Project	Nick Veretto
17:00	Adjourn to Informal Social Hour	

Table 2. Day 2 Workshop Agenda, September 7, 2006

Time	Topic	Presenter
8:00	Welcome	Randy Lee
8:15	Portland District Overview	Randy Lee
8:30	Bonneville First Powerhouse	Blaine Ebberts
9:00	Bonneville Second Powerhouse	Blaine Ebberts
9:30	The Dalles	Laurie Ebner
10:00	Break	
10:15	John Day	Brad Eppard
10:40	Seattle District: Howard Hansen	Dan Katz
11:05	Portland General Electric: Round Butte	Don Ratliff
11:35	Portland General Electric: North Fork	Doug Cramer
12:00	Lunch (on your own)	
13:00	Identification of Overarching Themes	Al Giorgi
13:30	Round-Table Discussion of Overarching Themes	Chick Sweeney
14:30	Break	
14:45	Continuation of Discussion	Chick Sweeney
15:45	Break	
16:00	Wrap-Up and Closing	Al Giorgi
16:30	Adjourn	

Round-Table Discussion of Overarching Themes

These notes document the discussion periods during the September 7th afternoon sessions. Where possible, notes are attributed to the workshop participant making the point. However, not all discussion points are included in these notes.

General Discussion Session 1: Overarching Themes

A) Location[3]

1) To maximize collection efficiency

- ***Situate entrances on known migratory pathways.***
  - Best collection results occur when the SFO is located on the migratory path. *(Chuck Peven)*
  - Define baseline fish behavior patterns upfront and be species specific. *(Steve Rainey)*
  - Fish typically follow the thalweg, although dam operations also influence pathways. *(Curt Dotson)*
- ***Situate entrances where juveniles congregate***
  - We must consider and understand the factors and mechanisms that influence migratory pathways and locations where juveniles congregate. Changing project operations may change flow patterns and possibly temperature gradient in the river basin. *(Rebecca Kalamasz)*

  - Location of an SFO must be considered relative to dam operations, i.e., competing flows. *(Kenneth Ham)*

- ***Guidance devices may be necessary- When?***
  - If you do not have a point of high fish concentration, guidance devices are necessary. *(Blaine Ebberts)*
  - Can overcome location issue with either guidance devices, or adjusting discharge to attract or guide fish to a location. *(Doug Cramer)*
  - Tributary (mountain) and main stem dams typically require different guidance devices. You often do not have a large zone of influence on tributary dams. The issue is whether there is sufficient water current to get the fish to the SFO. *(Bryan Nordlund)*

2) Egress conditions can influence outfall site selection.

- All components of the SFO must be considered from the outset. The outfall conditions can be as critical as the collector entrance and can influence the selection of the location of the entrance. The best upstream collection location may correspond to the worst outfall location in the tailrace. *(Mark Lindgren)*
- It is important to identify where predators are distributed; identify whether there is a predation problem or not upfront. Predation may be site specific. It is possible that more predators exist on one side of the river than the other. *(Steve Rainey)*
- Ask yourself if predators currently exist in certain locations in the tailrace. If they do not, will they begin congregating if you place the outfall and hence a large concentration of juveniles at a given location? Can't look at just the historical predator distribution; need to look at the outcome, too. *(Larry Swenson)*
- There are different ways to get good egress. Can address egress issues by: Excavation of a plunge pool, Training walls to direct and contain discharge in tailrace, Operations, and Location. *(Lynn Reese)*
- Egress conditions depend on project operations. *(Mike Langeslay).* But operations differ among projects, so good egress conditions will necessarily be site-specific. (*Brad Eppard*)
- There are a lot of hypotheses about what good egress conditions are, but not a lot of field data to support them. (*Duncan Hay*). There appears to be need for further egress research. *(Chick Sweeney).* The NMFS criteria for egress conditions were written for screen bypass systems with low flow outfall, not SFOs with high flow outfalls. (*Bryan Nordlund*). So, the question is, does it scale? (*Chick Sweeney*)
- Project operations alone should not be required to attain a high fish passage efficiency. Design should be robust and operate efficiently over a broad range of operating conditions, because realistically we do not always have control of operations and project priorities can change with time. *(Laurie Ebner)*
- As we examine both forebay collection and tailrace egress in SFO development, it will be important to think about what future operations might be. *(Marvin Shutters)*
- We need to consider that as energy demands increase, the improvement of spill may decrease in the future. Should we be designing SFOs for this possibility? *(Curt Dotson)*
- You'll need to accept restrictions on project operations if you don't place the outfall out of the influence of project operations, i.e., sometimes there'll be a need to accept restrictions on project operations in order to have good egress. (*Ed Meyer)*

3) High discharge outfalls have the potential to affect adult passage.

- This topic needs to be expanded to say we should examine all impacts of SFOs, e.g., effects on navigation. Identify all of them upfront, and then decide what level of impact is acceptable. *(Sean Milligan)*

B) Species matter

1) Salmonid species exhibit different collection efficiencies.

- Age and life history stage probably matter as well. *(Carl Schilt)*
- Make it clear that species matter because different species have different behaviors. (*Don Ratliffe*)
- Fish collection efficiency is affected by fish behavior which is affected by species. (*Doug Cramer*)
- What species are we trying to protect the most? (*Lynn Reese*). It depends on where you at, i.e., site-specific conditions, to know which species matter the most. (*Blaine Ebberts*). The species you focus on depend on what your goals are. (*Chuck Peven*)

2) Steelhead = highest FCE

- There may still be situations where steelhead are sounding and FCE is low.
- Are current design considerations being driven by important species only *(Lynn Reese)?* Steelhead show best performance because designs seem to favor their behaviors. If you design an SFO for sockeye, it would not look the same as one designed for steelhead. *(Duncan Hay).* Designing for the lowest performer may be a good idea. (*Steve Rainey*). The problem with design for a particular target specie is that another species may become important in the future. For example, we've focused on passing juvenile salmonids, but have we inadvertently impacted lamprey? Need to do the best you can for all species – this may require multiple configurations in the SFO system. (*Ed Meyer*)

3) Chinook & sockeye = lower FCE

- In some cases (Wells) deep slots have high collection efficiencies for both sockeye and steelhead: because the slot provides access for both shallow and deep species. Migratory behavior should be the first consideration, e.g., vertical distribution, channel/shoreline distribution. *(Bill Hevlin)*
- Sockeye often find the entrance of the SFO and decide not to go in. This rejection possibly occurs because we are missing an important design consideration. *(Chuck Peven)*

4) Not all species prefer an SFO, sounding through deep outlets is common (e.g. RR, B2).

- "Prefer" is anthropomorphic. It is the wrong word. (*Chuck Peven)*
- Why the reference to B2 in the statement? (*Blaine Ebberts*). Because fish sound to go into turbines at B2. (*Al Giorgi)*
- We need specific definitions of shallow and deep entry because they are relative to each project. *(Doug Cramer)*

5) Effects on lamprey unknown

- Lamprey are a concern, as are sturgeon. (*Carmen Andonaegui*)
- Although some species (such as lamprey) did not require restoration efforts before SFO development, their behavior was affected by SFO installation, and now these species need to be restored. *(Ed Meyer)*
- We may need additional SFO modifications for lamprey. *(Ed Meyer)*
- Perhaps we need to start appending salmon reports with incidental lamprey observations. *(Doug Cramer)*
- Lamprey are difficult to study in nature. *(Chuck Peven)*

6) What are management implications in terms of achieving standard goals for all species?

- We need to find overlap between species behavior when designing SFOs. One size will not fit all. The goal should be to find overlap in common behaviors and exploit these to drive the solution. (*Carmen Andonaegui)*
- Prioritizing species is a significant design challenge. (*Lynn Reese*) Prioritization will depend on location *(Blaine Ebberts)* and well defined goals that dictate species focus *(Chuck Peven).*

C) Hydraulic criteria are fuzzy

1) Effect of near-field current conditions (competing or complex flow-nets) may affect species differently, as evidenced by disparate encounter efficiencies.

- Define the connection between hydraulic conditions and biological performance. (Sean Milligan)
- It will be necessary to have different hydraulic criteria for different types of SFOs, i.e., criteria for subcritical SFOs will be different than those for critical SFOs. (Chick Sweeney)
- The current velocity gradient standard (0.2 ft/s/ft) may or may not be applicable across all types of entrances and dimensions. Perhaps, higher gradients are acceptable at critical entrances and lower gradients may be required at subcritical entrances where the channel narrows. *(Chick Sweeney)*

2) Entrance conditions that promote consistently high entry rates remain ill-defined.

- We must factor noise, light, scale effects, in addition to hydraulics when determining factors affecting FCE. Up to this point, many of our decisions depend on anecdotal evidence. *(Steve Rainey)*
- Criteria come in two flavors – relative and absolute. Fish respond to conditions relative to the background environment. Therefore, you can't have absolute criteria because conditions must be assessed relative to the environment they're in. To best design SFOs we may need design ratios rather than specific numbers. (John Nestler)
- The current design criterion is a velocity gradient (distance per time per distance); it is NOT acceleration (distance per time squared). Perhaps we need to examine what impact acceleration has on fish behavior. A body in the fluid feels acceleration. *(Duncan Hay)*
- We need a better description of near field: is it distance, time, etc..?(*Duncan Hay)* Perhaps it can not be further defined and is site specific. Also, does everyone agree with the SFO conceptual framework? Where did it come from? *(Rebecca Kalamasz).* The conceptual framework is an outgrowth of discussions and synthesis report development in various forums over the past 10 years. It is true that the distance scales for the zones (decision zone 0-10 m; discovery zone 10-100 m; approach zone 100-1000 m) are somewhat arbitrary. They are meant to provide a common terminology and concept; they are not meant to be absolute distances. (*Gary Johnson*)
- There is a lack of literature and discussion on 1-D velocity change verses 2-D or 3-D velocity changes. Should we work towards multi-dimensional guidelines *(Ken Hansen),* such as lateral sweeping velocities? *(Sean Milligan)*

3) Do we have analytical tools that can resolve these uncertainties?

- We need to further examine the connection between fish behavior and hydraulics with existing facility data and laboratory studies. *(Chuck Peven)*
- Need to evaluate performance relative to some baseline condition, e.g., fate of passive particles. (*Kenneth Ham*). That is, determine if fish movement differs from water movement. (*Chick Sweeney*)
- I like the idea of SFO types based on flow criticality. We may need to examine design criteria according to flow regime, and gauge criteria accordingly. *(Ed Meyer).* Yes, we'll need different criteria for different SFO types. (*Chick Sweeney*)

D) Development requires time

- We started at Rocky Reach in 1994 and we're still working on it. (*Chuck Peven*)

- You need basic information before beginning SFO design. It can take time to acquire this information, which may include: Bathymetry, Fish behavior, Forebay and tailrace flow patterns, and operation considerations. This means getting all parties involved in dam operation to the table. (*Rebecca Kalamasz and Laurie Ebner*)
- We had three years to succeed at Cowlitz Falls and it didn't work. (*Steve Fischer*)
- Perhaps we need to accept some risk when prototype testing surface bypass structures to achieve success. *(Noah Adams)* There is risk taking precedent at Priest Rapids. Get baseline information first, involve all players and evaluate risks. Some benefits can be achieved by cooperation *(Curt Dotson)*
- It can be difficult to accept risk when so much money is involved *(Chuck Peven),* but how can you put a dollar value on fish survival. *(Ed Meyer).*

E) No Silver Bullets

1) Designs are site-specific.

- One set of design criteria will not fit for all designs. It's like comparing gliders and jets. *(Laurie Ebner)*

2) Migratory patterns vary by site.

3) Hydraulic conditions vary by site.

- What are the hydrodynamic cues that fish respond to? This is the key question. (*John Nestler*)

4) Standard design criteria (hydraulic, structural configurations) are not applicable across all types/scales of surface collectors.

- There are some truisms in fish behavior. (*Doug Cramer*)
- It will be important to develop draft guidelines, but they should be viewed as a starting point. (*Bryan Nordlund*)
- What do you see as the product of this workshop? (John Kranda). Although the compendium may not come up with universal design criteria, it will provide insight into the design process and aid in the selection of SFO type. *(Chick Sweeney)*

5) Some standard design templates may emerge (e.g. RSW), which can be applied at a variety of sites.

- Conversely, there have been false starts. You should address these too to learn lessons on why a particular SFO failed. These will be important pieces of information. (*Ed Meyer*)

General Discussion
Session 2: Technical Issues

A) When is entrance shaping required?

- Entrance shaping can eliminate vortices. Need to know the criteria you're designing to though. *(Laurie Ebner)*
- Not sure these SFOs "attract" fish, but you certainly can create condition that they will not avoid. Entrance shaping can minimize fish avoidance. *(Duncan Hay)*
- Conflicting hydraulic conditions at an SFO entrance could cause fish to reject the entrance. Need to minimize fish avoidance. (*Bryan Nordlund*)
- People have seen fish hold up at separation zones. Shaping can minimize separation and fish holding. *(Chick Sweeny)*

- Entrance shaping can also be an important consideration in economics to maximize spill/water efficiency. (*Lynn Reese)*
- Isn't the notion of using entrance shaping to improve hydraulic conditions to minimize fish avoidance still a hypothesis? This needs further testing. (*Blaine Ebberts*). We do know that deceleration is not a good thing. The degree you shape to avoid deceleration is necessary design element. There is evidence for this from acoustic and radio telemetry studies at Wanapum and Rocky Reach. (*Duncan Hay*) At The Dalles sluice, fish are known to reject the sluice entrance but we still see fish collection efficiency relative to the powerhouse of about 40-45%. The hypothesis needs to be examined further. (*Blaine Ebberts*)
- DIDSON work at The Dalles sluiceway showed that juvenile salmonids rejected the large rapid acceleration that occurs as water passes over the sill into the sluice channel. The smaller the body of water the fish is in, the more shaping to smooth water acceleration will be necessary. If the fish is in a large volume of water, it doesn't sense where the entrance is before it is entrained, e.g., a RSW. Thus shaping is more important the smaller the SFO flow field is going into the entrance. The smaller the SFO volume of water, the more likely the fish is to sense adverse conditions at the edges. The TDA sluice might be more efficient if it was shaped. (*John Williams)*
- We are trying to achieve a specified velocity gradient with RSW shaping. Perhaps this is not an appropriate design criterion, as suggested previously by Duncan. (*Al Giorgi*)
- Rhetorically speaking, what is a fish responding to? Look at the flow field as an image from the fish's point of view. The fish picks the pathway of least distortion in the flow, i.e., it is looking for the "middle" of the river. Shaping has the effect of reducing the distortion in the flow; distortion is the spatial derivative of velocity. (*John Nestler*)
- Shaping may also influence hydraulics further from the entrance.(*Mark Lindgren)*
- Is velocity gradient or acceleration the proper design criterion*? (Steve Rainey)*
- Distortion of the hydraulic pathway may affect fish pathway and behavior. If we add roughness to distort a flow field, the fish will take the path of least disturbance. In nature sharp edges typically mean good predator hiding places. *(John Nestler)*
- Does the hypothesis that we need smooth hydraulic paths contradict Coutant's hypothesis that you need turbulence to attract/guide fish? (*Al Giorgi*). They are really complementary hypotheses and dynamics differ at different scales. Coutant would call this "turbulence guidance."(*John Nestler*)

B) Should we move more investigations into the lab?

- Many of the phenomena we are interested in might not be scaleable from the lab to the field. Perhaps we should consider laboratories in the field, i.e., more controlled conditions in the field. (Chick Sweeney)
- We need more fundamental knowledge on the relationship between fish behavior and hydraulics, whether in a lab or in the field. (*Larry Swenson*)
- Fish behavior may be hard to mimic in laboratory conditions. Some fish responses in a lab may be applicable to the field, e.g., response to acceleration, but not many will be. (*Marvin Shutters*)
- The data that we already have is not being fully utilized. There is a wealth of information for acoustic data and CFD correlation. In many cases we have the acoustic data – now we need to model with CFD, if not already done, and compare. (*Duncan Hay*)

C) When is trapping velocity necessary? 7 fps?

- We know deceleration can cause SFO rejection, as evidenced by acoustic testing at Wanapum and Rocky Reach. (*Duncan Hay*)
- Trapping velocities are necessary when we have "poor" hydraulic conditions downstream of the trapping point. If we improve our designs so fish never attempt to leave the bypass system, then we will not need to have trapping velocities. (*John Williams*)

- Trapping velocities are required for economic reasons: it may be far more expensive to continue fish attracting conditions. (*Chick Sweeney*)
- The 7ft/s trapping velocity is relative to what is available? The 7 ft/s criteria came from a study completed in the 70's- perhaps it is time to revisit this number. (*John Bailey)*

D) How much training spill is adequate?

- Training spill is site-specific and is defined by egress requirements. For example, we need sufficient flow to move fish past eddies in the near field tailrace. Even if predation is not a concern, we are still concerned about delay. (*Ed Meyer*)
- Isn't there a point in the tailrace where fish behavior determines fish distribution, i.e., the fish are not simply entrained? Need to know when fish distribution differs from dye in the physical models. (*Laurie Ebner*)
- Perhaps we need to do survival and/or egress studies with and without training spill in order to determine the required level of training spill. (*Bryan Nordlund*)
- Need to distinguish between training spill and voluntary spill.
- There is a practical limit to training spill. When you are spilling the whole river its just spill- not training spill. (*John Bailey).*
- The benefit of an RSW seems to be reduced delay in the forebay, but you also need additional spill for good egress. (*Ed Meyer*)

E) Hydro-combine is not a panacea (Wells vs. Cowlitz)

- We cannot compare Wells and Cowlitz. The forebay bathymetry produces different results (*Steve Fischer*). Wells does not have a trash deflector or a dewatering system, and there is a difference in the flow magnitude (*Chick Sweeney*).
- It's easier to distort a flow field than radically change the distribution of flow. (*John Nestler*)

F) Can diel patterns confuse interpretation of SFO performance?

- Fish have different vertical distributions and behavior on a diel basis. (*John Williams)*
- We can create artificial diel patterns based on adjusting SFO lighting, such as adding flood lights at night. (*Steve Rainey)*
- Maybe we need to track light operation at all of the SFOs to determine if lights affect night migration (*Doug Cramer*)

G) Is forebay delay a meaningful index of SFO performance?

- There is a definite benefit in decreasing the forebay delay. Less time in the forebay, means less predation. (*Blaine Ebberts*)
- Altering the forebay delay in terms of minutes means nothing, but days are significant. (*Marvin Shutters*)
- Although decreasing the forebay delay by hours may seem insignificant at one dam, when you add up the reduction in forebay delay over an entire river, a reduction of a few hours at each dam can mean more than a day's reduction in total travel time. (*Tim Dalton*)

H) To what extent is scale important (Outlet size and Q)?

- Very important because it will dictate your design. (*Chuck Peven*)
- When you select the flow you must think of the forebay and tailrace conditions. (*Steve* Rainey)
- In some cases, your typical powerhouse operation will dictate your design flow. (*Chick Sweeney*)

I) Do SFOs operate adequately over a broad range of conditions?

- We need robust designs that function well across broad operating conditions, because often operating conditions are out of our control. We need to consider both high and low flow years. (*Laurie Ebner*)

- No two fish will behave the same. Besides designing for the conditions that provide the best passage, we also need to design for the worst and include adaptability in our designs for future modifications, if required. (*Nick Veretto*)
- Prototype testing can help you identify the shortcomings of your design, so you do not need to factor as much adaptability into your final design. (*Chuck Peven*)
- Build in flexibility when you can. (*Mark Lindgren*)

General Discussion
Session 3: Management Issues

A) Well defined goals keep everyone on track.

- We need to work in a structured, formal process where there are agreed goals among fisheries managers, operators, and all stakeholders. Without goals, you a groping for an unknown. (*Chuck Peven*)
- We need to follow an agreed upon systematic design approach. (*Rebecca Kalamasz*)

B) Should achievement of survival goals trigger the endpoint of an SFO development effort?

- Survival goals need to be well-defined; they can be an end point. (*Carmen Andonaegui)*
- Goals depend on other responsibilities than just SFO, i.e. the Corps has multiple missions. (*Brad Eppard*)
- All of the goals are interim. Current FCE goals are an iterative process – we want total recovery and should keep striving toward the total recovery. (*Paul Wagner*)
- Answers depend on factors in addition to fish restoration: power generation and money.
- We need to get all fish survival up to a certain level on all dams before we strive for perfection. *(Mark Lindgren)*

C) How do SFO contribute to survival goals?

- ***Federal realm = system survival***
- ***Utility realm = project/dam survival***

D) Are goals practical in terms of expected performance across species?

- Goals are necessary for the process of achievement. *(Bryan Nordlund)*
- Incentives are also an important aspect to achieve goals *(Carmen Andonaegui)*

E) Are we at the point of diminishing returns on our SFO investment at some sites?

- When our improvement in FCE is less than our margin of error the money is not well spent. Do we even have the technology to measure this? (*Rebecca Kalamasz*)
- The last small increment of FCE improvement may be very expensive to achieve and possibly this money is better spent elsewhere. (*Al Giorgi*)

F) Can we effectively monitor all species? What about lamprey?

G) At some sites, are we on an endless loop- pursuing incremental improvements, involving great cost and complex and expensive monitoring without a realistic hope of reaching impractical or ill-defined goals?

Table 3. Workshop Attendees

Name		Affiliation
Last	First	
Adams	Noah	U.S.G.S., B.R.D.
Andonaegui	Carmen	WDFW Region 2 Office
Bailey	John	USACE Walla Walla District
Baxter	Rex	USACE Walla Walla District
Chong	Randy	USACE Walla Walla District
Cramer	Doug	PGE
Crum	Kevin	USACE Walla Walla District
Dotson	Curt	Public Utilities Dist. No. 1 of Grant County
Ebberts	Blaine	USACE Portland District
Ebner	Laurie	USACE Portland District
Eppard	Brad	USACE Portland District
Feil	Dan	USACE Walla Walla District
Fischer	Steve	Tacoma Power
Fodrea	Kim	Bonneville Power Admin – EWI
Fransen	Steve	NMFS
Fredricks	Gary	Environmental & Technical Services Division, NMDS
Giorgi	Al	BioAnalysts
Goodwin	Andy	USACE ERDC
Hall	Becca	ENSR
Ham	Kenneth	Battelle - PNNL
Hansen	Ken	USACE Walla Walla District
Hanson	Matt	USACE Portland District
Hay	Duncan	Oakwood Consulting, Inc.
Hevlin	Bill	Environmental & Technical Services Division, NMFS
Higginbotham	Fred	USACE Walla Walla
Jeske	Dana	Public Utilities Dist. No. 1 of Grant County
Johnson	Gary	Battelle
Kalamasz	Rebecca	USACE Walla Walla District
Katz	Dan	USACE Seattle District
Klinge	Rick	Public Utilities Dist. No. 1 of Douglas County
Kranda	John	USACE Portland District
Kruger	Rick	Oregon Dept. of Fish & Wildlife
Kuhn	Karen	USACE Portland District
LaRiviere	Mark	Tacoma Power
Lee	Randy	USACE Portland District
Lindgren	Mark	USACE Walla Walla District
Meyer	Ed	Environmental & Technical Services Division, NMFS
Miller	Mark	BioAnalysts
Milligan	Sean	USACE Walla Walla District
Nestler	John	USACE ERDC
Nordlund	Bryan	Environmental & Technical Services Division, NMFS
Ocker	Paul	USACE Portland District
Peven	Chuck	Public Utilities Dist. No. 1 of Chelan County
Ploskey	Gene	
Rainey	Steve	GEI Consultants

Name		Affiliation
Last	First	
Ratliff	Don	Portland General Electric
Reese	Lynn	USACE Walla Walla District
Ruff	Jim	NW Power Planning Council
Sands	Jack	USACE Walla Walla
Schilt	Carl	Senior Biologist, LGL Ltd. Environmental Associates
Scott	Shane	4719 NE Salmon Creek Street
Setter	Ana	USACE Walla Walla
Shutters	Marvin	USACE Walla Walla District
Smith	Mark	USACE Walla Walla
Sweeney	Chick	ENSR
Sweet	Jason	Bonneville Power Admin – EWI
Swenson	Larry	Environmental and Technical Services Division, NMFS
Veretto	Nick	Puget Sound Energy
Wagner	Paul	NOAA Fish - Portland
Wicke	Mark	Tacoma Power
Wik	Tim	COE - Walla Walla
Williams	John	Coastal Zone & Estuarine Studies Division, NMFS

ENSR | AECOM

Appendix B

Master Biological and Hydraulic SFO Characteristics Matrices

Appendix B, Table. Bio-index Data.

Summary Table

Project	SFO	Yearling Chinook	Steel-head	Coho	Sockeye	Run-at-Large Spring	Bio Index Spring	Subyearling Chinook	Run-at-Large Summer	Bio Index Summer
Rocky Reach	Forebay Collector	0.30	0.67		0.37		0.45	0.25		0.25
Wanapum	Retrofit - SAC					0.00	0.00		0.00	0.00
Cowlitz Falls	Retrofit Baffle	0.21	0.48	0.30			0.33			
Wells	Retrofit Baffle Bays					0.89	0.89		0.89	0.89
Bonneville First Powerhouse	Retrofit PSC	0.43	0.45				0.44			
Lower Granite	Retrofit SBC	0.29	0.23			0.43	0.32			
Bonneville First Powerhouse	Sluiceway	0.49	0.55			0.34	0.46	0.58	0.46	0.52
Priest Rapids	Sluiceway	0.02				0.05	0.03		0.04	0.04
The Dalles	Sluiceway	0.11	0.10			0.14	0.11	0.06	0.08	0.07
Wanapum	Sluiceway	0.03				0.06	0.05		0.06	0.06
Ice Harbor	Sluiceway (1982, 83)					0.32	0.32			
Bonneville Second Powerhouse	Sluiceway B2CC	0.33	0.70			0.32	0.45	0.39	0.42	0.40
Wanapum	Surface Spill	0.17					0.17			
Ice Harbor	Surface Spill RSW	0.40	0.42			0.28	0.37		0.38	0.38
Lower Granite	Surface Spill RSW	0.45	0.54			0.48	0.49	0.64	0.25	0.44
	Mean	0.27	0.46	0.30	0.37	0.30	0.33	0.38	0.29	0.31

Raw Data

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
Wells	Retrofit Baffle Bays	Yearling Chinook	1998	nd	nd	nd	nd	nd	0.997	nd	Klinge's SFO presentation
		Steelhead	1999	nd	nd	nd	nd	nd	0.943	nd	Klinge's SFO presentation
			2000	nd	nd	nd	nd	nd	0.946	nd	Klinge's SFO presentation
			mean						0.945		
		Run-at-Large Spring	1990	nd	nd	0.84	16.9	nd	nd	nd	Skalski et al. 1996 (table 5)
			1991	nd	nd	0.95	19.0	nd	nd	nd	Skalski et al. 1996 (table 5)
			1992	nd	nd	0.89	17.8	nd	nd	nd	Skalski et al. 1996 (table 5)
			mean			0.89	17.9				Skalski et al. 1996 (arithmetic mean; see explanation in text)
		Run-at-Large Summer	1990	nd	nd	0.77	15.3	nd	nd	nd	Skalski et al. 1996 (table 5)
			1991	nd	nd	0.97	19.4	nd	nd	nd	Skalski et al. 1996 (table 5)
			1992	nd	nd	0.93	18.7	nd	nd	nd	Skalski et al. 1996 (table 5)
			mean			0.89	17.8				Skalski et al. 1996 (arithmetic mean; see explanation in text)
Rocky Reach	Forebay Collector	Yearling Chinook	2004	nd	nd	0.27		nd	nd	nd	Steig et al. 2007 (efficiency estimates)
			2005	nd	nd	0.32		nd	nd	nd	Steig et al. 2007 (efficiency estimates);Calculated

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
											entrance Eff. reflects joint probability of entering and passing through SFO
			2006	nd	nd	nd		nd	nd	nd	Steig et al. 2007 (efficiency estimates)
			Mean			0.30					
		Steelhead (ROR)	2004	nd	nd	0.67		nd	nd	nd	Steig et al. 2007 (efficiency estimates)
			2005	nd	nd	0.68		nd	nd	nd	Steig et al. 2007 (efficiency estimates)
			2006	nd	nd	0.66		nd	nd	nd	Steig et al. 2007 (efficiency estimates)
			Mean			0.67					
		Sockeye (ROR)	2004	0.446	0.90	0.383		nd	nd	nd	
(based on concentric arc analyses, Steig et al. 2007)			2005	0.383	0.81	0.314		0.953	nd	nd	Skalski and Townsend 2005 (survival); Steig et al. 2007 (efficiency estimates)
			2006	0.408	0.95	0.417		0.990	nd	nd	Skalski et al. 2006 (draft-survival); Steig et al. 2007 (efficiency estimates)
			Mean	0.41	0.89	0.37		0.972			
		Subyearling Chinook	2004	na	na	0.25		0.965	nd	nd	Skalski et al. 2005 (survival); Steig et al. 2007 (efficiency estimates)
Rock Island	Standard Spillbay (1997)	Yearling Chinook	1997					0.984			Skalski and Giorgi 1999
	Slotted Spillbay (1997)	Yearling Chinook	1997					0.951			Skalski and Giorgi 1999

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
	Spillway 1 (2005)	Chinook (Yearling ROR)	2005					0.9904			Skalski and Townsend 2005:not in reference list
	Spillway 2 (2005)	Chinook (Yearling ROR)	2005					0.9758			Skalski and Townsend 2005:not in reference list
	Combined Spillway	Chinook (Yearling Hatchery)	2004			0.386			0.98		Steig et al. 2006
	(1999, 04, 05)	Chinook (Yearling ROR)	2005			0.362					Steig et al. 2006
		Yearling Chinook	mean			0.374					Steig et al. 2006
		Chinook (Subyearling ROR)	2004			0.376					
		Steelhead	1999			0.285			1		Lady et al. 2000
		Steelhead (ROR)	2004			0.167					Steig et al. 2006
		Steelhead (ROR)	2005			0.201					Steig et al. 2006
		Steelhead (Hatchery)	2005			0.219					Steig et al. 2006
			mean			0.218					
		Sockeye (ROR)	2004			0.550					Steig et al. 2006
		Sockeye (ROR)	2005			0.290					Steig et al. 2006
			mean			0.420					
		Run-at-Large Spring	1998			0.277					Iverson and Birmingham 1998
		Run-at-Large Summer	1998			0.331					Iverson and Birmingham 1998

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
Wanapum	Sluiceway	Run-at-Large Spring	1989			0.086					Ransom 1997
	(1989-91, 95, 96, 01, 02)		1990			0.057					Ransom 1997
			1991			0.042					Ransom 1997
			1995			0.100					Ransom 1997
			1996			0.030					Ransom 1997
			Mean			0.063					Ransom 1997
		Run-at-Large Summer	1994			0.058					Ransom 1997
			1995			0.099					Ransom 1997
			1996			0.037					Ransom 1997
			Mean			0.065					Ransom 1997
		Chinook (Hatchery)	1996						0.974		Normandeau et al 1996
		Chinook (Hatchery)	2001						0.839		Robichaud et al. 2003
		Chinook (ROR)	2002			0.03			0.890		Robichaud et al. 2003; One-route RSSM
		Yearling Chinook	Mean			0.029			0.901		
		Steelhead	2000						0.93		Smith et al. 2000
	Retrofit - SAC (1996, 97)	Chinook (ROR)	1996	0.14							Normandeau et al. 1996;
		Chinook (ROR)	1997	0.11							Normandeau et al. 1998;
		Yearling Chinook	Mean	0.13							
		Steelhead (ROR)	1996	0.31							Normandeau et al. 1996;
		Steelhead (ROR)	1997	0.23							Normandeau et al. 1998;
		Steelhead	Mean	0.27							
		Run-at-Large	1996			0.003					

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
		Summer Run-at-Large Spring	1997			0.003					Kumagai et al. 1997; FCE varied 0.1-0.5%
	Surface Spill	Chinook (ROR)	2002			0.10			0.876		Robichaud et al. 2003; One-route RSSM
	(top)	Chinook (Hatchery)	2003						1.001		2004 BiOp
		Chinook (??)	2004			0.24					??
		Yearling Chinook	Mean			0.17		0.945	0.94		
	Overflow wier (2,000 cfs)	Yearling Chinook	1996					0.920			Normandeau et al 1996
	(4,000 cfs)	Yearling Chinook	1996					0.969			Normandeau et al 1996
Priest Rapids	Sluiceway	Run-at-Large Spring	1992			0.027					McFadden et al. 1993
	(1992, 95-96, 01-03)		1995			0.083					Ransom 1997
			1996			0.032					Ransom 1997
			Mean			0.047					Ransom 1997
		Run-at-Large Summer	1992			0.038					Ransom 1997
			1994			0.029					Ransom 1997
			1995			0.057					Ransom 1997
			1996			0.028					Ransom 1997
			Mean			0.038					Ransom 1997
		Chinook (Hatchery)	2001						0.926		2004 BiOp
		Chinook (ROR)	2002			0.019			0.914		2004 BiOp;Robichaud et

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
											al. 2003
		Chinook (Hatchery)	2003						0.822		2004 BiOp
		Yearling Chinook	Mean						0.887		
Lower Granite	Retrofit SBC	Run-at-Large Spring	2000	nd	0.76	0.43	11.0	nd	nd	nd	Anglea et al. 2001 (p.4.2, mean SH and SL treatments)
		Yearling Chinook	2000	nd	0.84	0.29	6.7	nd	nd	nd	Plumb et al. 2002 (p.26,32, mean SH and SL treatments)
		Steelhead (wild)	2000	nd	0.60	0.27	6.2	nd	nd	nd	Plumb et al. 2002 (p.26,32, mean SH and SL treatments)
		Steelhead (hatchery)	2000	nd	0.42	0.18	3.6	nd	nd	nd	Plumb et al. 2002 (p.26,32, mean SH and SL treatments)
	Surface Spill RSW	Run-at-Large Spring	2002	nd	nd	0.65	8.7	nd	nd	nd	FCE from Wik memo; FCF Anglea et al. 2003 (p.iv)
			2005	nd	nd	0.31	11.3	nd	nd	nd	Dawson et al. 2006 (p.1)
			2006	nd	nd	not reported yet		nd	nd	nd	
			mean			0.48	10.0				
		Run-at-Large Summer	2002	nd	nd	nd	nd	nd	nd	nd	
			2005	nd	nd	0.25	3.3	nd	nd	nd	Dawson et al. 2006 (p.1)
			2006	nd	nd	not reported yet		nd	nd	nd	
			mean			0.25	3.3				
		Subyearling Chinook	2005	nd	nd	0.69	nd	0.924	nd	nd	memo from Wik, May 2007 (RSW on)
			2006	nd	nd	0.58	nd	nd	nd	nd	memo from Wik, May 2007 (RSW on with training spill;

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
											combined)
			mean	nd	nd	0.64	nd	0.92	nd	nd	
		Yearling Chinook	2002	0.6	0.89	0.56	6.5	0.981	nd	0.016	Plumb et al. 2003 (Table 14, p.64, RSW on); Surv . Normandeau et al. 2003 (table 3-1, 48-h, table 3-2, mean for the 3 releases)
			2003	0.49	0.95	0.58	8.3	nd	nd	nd	Plumb et al. 2004 (Table 21, p.67, RSW on)
			2005	nd	nd	0.37	nd	0.984	nd	nd	memo from Wik, May 2007 (RSW on)
			2006	nd	nd	0.30	nd	0.982	nd	nd	memo from Wik, May 2007 (RSW on)
			mean	0.545	0.92	0.45	7.4	0.982	nd	0.016	
		Steelhead (wild)	2002	0.72	0.90	0.61	7.1	nd	nd	nd	Plumb et al. 2003 (Table 14, p.64, RSW on); Surv . Normandeau et al. 2003 (table 3-1, 48-h, table 3-2, mean for the 3 releases)
			2003	0.63	0.94	0.67	9.6	nd	nd	nd	Plumb et al. 2004 (Table 21, p.67, RSW on)
			2005	nd	nd	0.49	nd	nd	nd	nd	
			2006	nd	nd	nd	nd	nd	nd	nd	
			mean	0.675	0.92	0.59	8.3				
		Steelhead (hatchery)	2002	0.73	0.96	0.62	7.2	nd	nd	nd	Plumb et al. 2003 (Table 14, p.64, RSW on); Surv . Normandeau et al. 2003 (table 3-1, 48-h, table 3-2, mean for the 3 releases)

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
			2003	0.67	0.91	0.69	9.9	nd	nd	nd	Plumb et al. 2004 (Table 21, p.67, RSW on)
			2005	nd	nd	0.41	nd	nd	nd	nd	
			2006	nd	nd	0.27	nd	0.971			memo from Wik, May 2007 (RSW on)
			mean	0.7	0.94	0.50	8.5	0.971			
Ice Harbor	Sluiceway (1982, 83)	Run-at-Large Spring	1982	nd	nd	0.13	8.7	nd	nd	nd	Johnson et al. 1982 (p.22)
			1983	nd	nd	0.30	13.6	nd	nd	nd	Johnson et al. 1983 (p.18)
			1986	nd	nd	0.50	22.9	nd	nd	nd	Sullivan et al. 1986 (p.23)
			1987	nd	nd	0.34	6.8	nd	nd	nd	Ransom and Ouellette 1988 (p.6)
			mean			0.32	13.0				
	Surface Spill RSW	Run-at-Large Spring	2005			0.28		nd	nd	nd	memo from Wik, May 2007 (RSW on)
			2006			not reported yet		nd	nd	nd	
			mean			0.28					
		Run-at-Large Summer	2005			0.38		nd	nd	nd	memo from Wik, May 2007 (RSW on)
			2006			not reported yet		nd	nd	nd	
			mean			0.38					
		Subyearling Chinook	2005			0.6		0.970	nd	nd	memo from Wik, May 2007 (RSW on)
			2006			0.68		0.980			memo from Wik, May 2007 (RSW on)
			mean			0.64		0.98			
		Yearling Chinook	2005	nd	nd	0.29	3.1	0.970			Axel et al. 2006
			2006	nd	nd	0.51	7.3	0.947			memo from Wik, May 2007 (RSW on w/ 30-

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
											40% spill)
			mean			0.40	5.20	0.96			
		Steelhead	2005	nd	nd	0.47	5.2	0.985			Axel et al. 2006
			2006	nd	nd	0.38	5.4	1.017			memo from Wik, May 2007 (RSW on w/ 30-40% spill)
			mean			0.42	5.30	1.00			
The Dalles	Sluiceway	Run-at-Large Spring	1999	nd	nd	0.13	8.6	nd	nd	nd	Ploskey et al. 2001a (1999 study)
			2000	nd	nd	0.06	3.2	nd	nd	nd	Moursund et al. 2001
			2001	nd	nd	0.18	6.0	nd	nd	nd	Moursund et al. 2002
			2002	nd	nd	0.25	13.0	nd	nd	nd	Johnson et al. 2003
			2004	nd	nd	0.07	3.3	nd	nd	nd	Johnson et al. 2005
			mean			0.14	6.8				
		Run-at-Large Summer	1999	nd	nd	0.12	8.6	nd	nd	nd	Ploskey et al. 2001a (1999 study)
			2000	nd	nd	0.07	3.3	nd	nd	nd	Moursund et al. 2001
			2001	nd	nd	0.05	1.4	nd	nd	nd	Moursund et al. 2002
			2002	nd	nd	0.11	7.6	nd	nd	nd	Johnson et al. 2003
			2004	nd	nd	0.04	1.7	nd	nd	nd	Johnson et al. 2005
			mean			0.08	4.5				
		Subyearling Chinook	2002	nd	nd	0.08	5.7	0.907			Hausman et al. 2004; Counihan et al. 2006a
			2003	nd	nd	0.12	nd	nd			Hansel et al. 2004
			2004	nd	nd	0.07	2.8	0.735	0.804		Hansel et al. 2005; Counihan et al. 2006b
			2004	nd	nd	0.01	0.4	nd			Cash et al. 2005
			2005	nd	nd	0.04	1.1	0.931			Beeman et al. 2006
			mean			0.06	2.5	0.858	0.804		
		Yearling Chinook	2002	nd	nd	0.10	6.7	0.911			Hausman et al. 2004; Counihan et al. 2006a

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
			2003	nd	nd	0.17	nd	nd			Hansel et al. 2004
			2004	nd	nd	0.07	4.0	0.981	0.957		Hansel et al. 2005; Counihan et al. 2006b
			2004	nd	nd	0.08	3.6	nd			Cash et al. 2005
			2005	nd	nd	0.11	3.4	1.006			Beeman et al. 2006
			mean			0.11	4.4	0.966	0.957		
		Steelhead	2002	nd	nd	0.14	9.3	nd			Hausman et al. 2004
			2003	nd	nd	nd	nd	nd			Hansel et al. 2004
			2004	nd	nd	nd	nd	nd			Hansel et al. 2005
			2004	nd	nd	0.05	2.4	nd			Cash et al. 2005
			2005	nd	nd	nd	nd	nd			Beeman et al. 2006
			mean			0.10	5.9				
Bonneville First Powerhouse	Sluiceway	Subyearling Chinook	2000	nd	nd	0.68	nd	nd		nd	Evans et al. 2006 (October version; revised for corrected spill; table 18, p.29)
			2001	nd	nd	0.70	nd	nd		nd	Evans et al. 2006 (October version; revised for corrected spill; table 18, p.29)
			2002	nd	nd	0.48	28.0	nd		nd	Evans et al. 2006 (October version; revised for corrected spill; table 18, p.29)
			2004	nd	nd	0.47	3.7	nd		nd	Evans et al. 2006 (October version; revised for corrected spill; table 18, p.29)
			2005	nd	nd			nd		nd	
			mean			0.58	15.9				
		Yearling Chinook	2000	nd	nd	0.29	nd	nd		nd	Regan et al. 2006 (revised for corrected spill; table 18, p.33); Counihan et al. 2006a

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
			2001	nd	nd	0.77	nd	nd		nd	Regan et al. 2006 (revised for corrected spill; table 18, p.33)
			2002	nd	nd	0.35	18.6	nd		nd	Regan et al. 2006 (revised for corrected spill; table 18, p.33)
			2004	nd	nd	0.53	14.6		0.919		Regan et al. 2006 (revised for corrected spill; table 18, p.33)
			2005	nd	nd				0.937		Counihan et al. 2006b
			mean			0.49	16.6		0.928		
		Steelhead	2000	nd	nd	0.44	nd	nd		nd	Regan et al. 2006 (revised for corrected spill; table 18, p.33); Counihan et al. 2006a
			2001	nd	nd	nd	nd	nd		nd	Regan et al. 2006 (revised for corrected spill; table 18, p.33); Counihan et al. 2006a
			2002	nd	nd	0.65	34.1				Regan et al. 2006 (revised for corrected spill; table 18, p.33); Counihan et al. 2006a
			2004	nd	nd	0.55	15.1		0.985		Regan et al. 2006 (revised for corrected spill; table 18, p.33); Counihan et al. 2006a
			2005	nd	nd				0.933		Counihan et al. 2005b
			mean			0.55	24.6		0.959		
		Run-at-Large	2002	nd	nd	0.33	14.0	nd	nd	nd	Ploskey et al. 2003

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
		Spring									
			2004	nd	nd	0.33	7.6	nd	nd	nd	Ploskey et al. 2005
			2005	nd	nd	0.37	7.6	nd	nd	nd	Ploskey et al. 2006 (table 3.1, p.3.17)
			mean			0.34	9.7	nd	nd	nd	
		Run-at-Large Summer	2002	nd	nd	0.29	2.7	nd	nd	nd	Ploskey et al. 2003
			2004	nd	nd	0.38	9.3	nd	nd	nd	Ploskey et al. 2005
			2005	nd	nd	0.71	4.3	nd	nd	nd	Ploskey et al. 2006 (table 3.1, p.3.17)
			mean			0.46	5.4				
Bonneville First Powerhouse	Retrofit PSC	Yearling Chinook	2000	0.63	0.72	0.43	8.0	nd	nd	nd	Evans et al. 2001
	(2000)'	Steelhead	2000	0.74	0.60	0.45	8.4	nd	nd	nd	Evans et al. 2001
		Run-at-Large Spring	2000	nd	nd	0.83	3.3	nd	nd	nd	Ploskey et al. 2000
		Run-at-Large Summer	2000	nd	nd	0.84	3.4	nd	nd	nd	Ploskey et al. 2000
Bonneville Second Powerhouse	Sluiceway B2CC	Subyearling Chinook	2004	nd	nd	0.37	5.6	1.010			FCE: Evans et al. 2005; Surv: Counihan et al. 2005
	(2004-05)		2005	nd	nd	0.40	5.9	1.020			FCE: Farley et al. 2006; Surv. Counihan et al. 2006
			mean			0.39	5.8	1.015			
		Yearling Chinook	2004	nd	nd	0.37	7.0	1.020			FCE: Regan et al. 2005; Surv: Counihan et al. 2005
			2005	nd	nd	0.29	5.9	1.020			FCE: Regan et al. 2006; Surv. Counihan et al. 2006

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
			mean			0.33	6.5	1.020			
		Steelhead	2004	nd	nd	0.74	14.2	1.010			FCE: Regan et al. 2005; Surv: Counihan et al. 2005
			2005	nd	nd	0.66	13.2	1.010			FCE: Regan et al. 2006; Surv. Counihan et al. 2006
			mean			0.70	13.7	1.010			
		Run-at-Large Spring	2004	nd	nd	0.31	5.8	nd	nd	nd	Ploskey et al. 2005
			2005	nd	nd	0.32	5.8	nd	nd	nd	Ploskey et al. 2006 (table 3.1, p.3.17)
			mean			0.32	5.8				
		Run-at-Large Summer	2004	nd	nd	0.40	8.2	nd	nd	nd	Ploskey et al. 2005
			2005	nd	nd	0.44	6.8	nd	nd	nd	Ploskey et al. 2006 (table 3.1, p.3.17)
			mean			0.42	7.5				
Mayfield	Forebay Collector (1964-65, 2001)	Coho	1964			0.50					SFO presentation 2006
			1965			0.62					SFO presentation 2007
		Coho (Hatchery)	2001			0.67					
			mean			0.59					SFO presentation 2008 Zapel et al. 2002
		Yearling Chinook	1964			0.76					SFO presentation 2006
			1965			0.74					SFO presentation 2006
			mean			0.75					SFO presentation 2006
		Steelhead	1964			0.736					SFO presentation

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
											2006
			1965			0.793					SFO presentation 2006
			Mean			0.76					SFO presentation 2006
Cowlitz Falls	Retrofit Baffle (1997-02, 06)	Steelhead	1997			0.45					BiOp 2004;Estimated system FCE
			1998			0.19					BiOp 2004;Estimated system FCE
			1999			0.41					BiOp 2004;Estimated system FCE
			2000			0.65					BiOp 2004;Estimated system FCE
			2001			0.58					BiOp 2004;Estimated system FCE
			2002			0.56					BiOp 2004;Estimated system FCE
			???			0.52					SFO Presentation 2006
			2006			0.45					SFO Presentation 2006
			Mean			0.48					
		Coho	1997			0.21					BiOp 2004;Estimated system FCE
			1998			0.32					BiOp 2004;Estimated system FCE
			1999			0.17					BiOp 2004;Estimated system FCE
			2000			0.45					BiOp 2004;Estimated system FCE
			2001			0.42					BiOp 2004;Estimated system FCE
			2002			0.33					BiOp 2004;Estimated system FCE
			???			0.31					SFO Presentation 2006

Project	SFO	Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
			2006			0.22					SFO Presentation 2006
			Mean			0.30					
		Yearling Chinook	1997			0.17					BiOp 2004;Estimated system FCE
			1998			0.18					BiOp 2004;Estimated system FCE
			1999			0.24					BiOp 2004;Estimated system FCE
			2000			0.24					BiOp 2004;Estimated system FCE
			2001			0.23					BiOp 2004;Estimated system FCE
			2002			0.22					BiOp 2004;Estimated system FCE
			???			0.19					
			mean			0.21					SFO Presentation 2006

Project	Geographic Location			Present Status (Existing, Under Development, Future, Inactive)	Project Layout (Linear, Z-dam, Cl-de-sac, split by island or other feature, or other)	Collector Entrance Flow Regime (Critical or Subcritical)	Collector Configuration Description	Collector Approach Flow Pattern (Upwelling and/or eddying that concentrates flow/fish or not)	Forebay Guidance Device (Yes or No) If yes, trash booms deep fixed or floating barriers, nets, or other.	Entrance shaping (Yes or No) (describe)	Conveyance Description: Dewatering or Screening? (Yes or No)	Channel Description (Spillway ogee, open channel flow, or closed conduit flow)	Channel Shape (Rectangular, circular, or other)	Conveyance Flow Regime (subcritical or supercritical)	Outfall Description: Plunging, Skimming Submerged, or variable outfall	Outfall flow (cfs)	Does outfall satisfy NMFS 25 ft/s jet entry criterion or other? (Yes or No)	Type of Hydraulic Information Available (Field, CFD, Physical Model)	Project Head (ft)	Forebay Depth at SFO Structures (ft)	SFO Entrance depth/Forebay Depth	Significant Forebay Bathymetric Features (deep holes, berms/sills, etc.)	Number of SFO Entrances	Entrance Width (ft)	Width at Crest (ft)	Entrance Depth (ft) *	Depth at Crest (ft) *	Min Distance from SFO Entrance Centerline to Boundary (ft)	Total Entrance Area (sq ft)	Design Flows (cfs): SFO Design Collection Flow (cfs)	SFO Unit Discharge (cfs/ft)	Powerhouse Capacity or Outlet Capacity if no Powerhouse (cfs)	Does SFO satisfy NMFS 0.2 ft/s-ft Maximum entrance velocity gradient criterion or other?	Average Entrance Velocity (fps) *	Velocity at Crest if Critical Entrance (fps)	Maximum Entrance Velocity Gradient Before Capture (ft/s-ft)	Collection Flow % of Powerhouse Capacity	Type of Biological Data Available (Fixed or Scanning Hydroacoustic, Radio Tag, Acoustic Tag, Didson Camera)	Comments	Biological Performance: Spring Bio Index	Summer Bio Index	Spring Effectiveness	Summer Effectiveness
Bonneville 1st Powerhouse Prototype Surface Collector	Bonneville, OR	on the	Columbia River	Inactive	Split by Island	Subcritical	Forebay Collector	None	No, but has wing-wall extending 150 ft. upstream between Units 6 & 7	Yes, Deep vertical slot configuration.	No	n.a.	Rectangular	n.a.	n.a.	n.a.	n.a.	All Three	40-68	77	0.58	None	6	20.00	20.00	44.50	44.50	10	5340	20,000	167	136,000	No	3.7	n.a.		14.7%	Hydroacoustic, Radio tag, Acoustic Tag	Did not collect fish, allowed to pass through turbine	0.44		2.99	0.00
Bonneville 1st Powerhouse Sluice	Bonneville, OR,	on the	Columbia River	Existing	Split by Island	Critical, Subcritical: dependent on forebay EL.	High Flow Sluice	None	No, but has wing-wall extending 150 ft. upstream between Units 6 & 7	No	No	Open Channel	Other	Subcritical	Variable. Dependent on tailwater EL 7-35 ft.	1500	Dependent on tailwater EL 7-35 ft.	All Three	40-68	77	0.09	None	3	21.00	21.00	7.00	7.00	3.5	441	1,500	24	136,000	No	3.4	3.4		1.1%	Radiotelemetry, hydroacoustic		0.46	0.52	41.59	47.20
Bonneville 2nd Powerhouse Corner Collector	Bonneville, OR	on the	Columbia River	Existing	Split by Island	Critical	High Flow Sluice	Eddying that Concentrates Flow/Fish	No	No	No	Open Channel	Rectangular	Supercritical	Variable	5300	Other: High Flow Outfall Guidelines	All Three	40-68	97	0.23	Complicated bathymetry with sill at forebay entrance	1	15.00	15.00	22.00	22.00	7.5	330	5,300	353	152,000	No	16.1	16.1	0.90	3.5%			0.45	0.40	12.86	11.54
Bonneville 2nd Powerhouse Ice Trash Sluice Chute	Bonneville, OR	on the	Columbia River	Inactive	Split by Island	Critical	High Flow Sluice	Eddying that Concentrates Flow/Fish	No	No	No	Open Channel	Rectangular	Supercritical	Variable	3000	No	All Three	40-68	14-97		Complicated bathymetry with sill at forebay entrance	1	15.00	13.00	13.00	13.00	6.5	195	3,000	200	152,000	No	15.4	17.8		2.0%						
Cowlitz Falls Fish Screen	Randle, WA	on the	Cowlitz River	Under Development	Hydrocombine	Subcritical	Powerhouse Retrofit	None	No	Yes, Screens	Yes	Open Channel	Rectangular	Subcritical	n.a.	n.a.	n.a.	Field, CFD	88	145	0.14	Cofferdam remnant	1	20.00	20.00	20.00	20.00	10	400	250	13	5,250	No	0.6	n.a.	0.29	4.8%	Radio tag, Didson Camera, Mark/Recapture	Trap and Haul	0.33		6.93	0.00
Howard Hanson Fish Collection System	Palmer, WA	on the	Green River	Future	Cul-de-sac	Subcritical	Powerhouse Retrofit	None	No	Yes	Yes	closed conduit flow	circular	Subcritical	n.a.	n.a.	n.a.	CFD, Physical model	120	140		Deep river thalweg	2	22.00	22.00	17.00	17.00	8.5		1,200		10,000	Yes	1.6	1.6	0.20	12.0%	None	Only outlet, Trap and Haul				
Ice Harbor RSW	Pasco, WA	on the	Snake River	Existing	Linear	Critical	Surface Spill	Gradual Symmetrical Approach	No	Yes, rounded, gradually shaped side piers and floor approach	No	Spillway Ogee	Rectangular	Supercritical	Varies	8400	No	All three	100	110	0.22	None	1	63.16	48.00	24.00	15.00	12	1515.79	8,400	133	106,000	No	5.5	11.7	0.32	7.9%	Fixed Hydroacoustic, radio tag, balloon tag		0.37	0.51	4.67	6.44
Ice Harbor Sluice	Pasco, WA	on the	Snake River	Inactive	Linear	Critical	High Flow Sluice	None	No	No	No	Open Channel	Rectangular	Subcritical	Plunging	2700	No		100	110	0.04	None	3	18.00	18.00	4.00	4.00	2	216	2,700	50	106,000	No	12.5	12.5		2.5%	Hydroacoustic, fykenet		0.32		12.50	0.00
John Day Spillway Bulkhead	Rufus, OR	on the	Columbia River	Future	Linear	Critical	Surface Spill	None	No	Yes	No	Spillway Ogee	Rectangular	Supercritical	Plunging	10000	No	Physical Model	100	120		None	1	50.00	48.00	14.56	2.44	7.27984	727.984	10,000	200	322,000		13.7	14.3		3.1%	Hydroaccoustic	Prototype test				
Little Goose ASW	Near Starbuck, WA	on the	Snake River	Under Development	Linear	Critical	Surface Spill	Gradual Symmetrical Approach	Yes, floating debris boom	Yes, pier extension on the spillbay	No	Spillway Ogee	Rectangular	Supercritical	Skimming or Undular (design incomplete)	12000	Deflected spillway jet	CFD, Physical model	100	135		thalweg closer to the north shore; shallower shelf in front of the powerhouse	1	63.16	48.00	20	20	24		12,000		130,000	Max entrance velocity gradient is about 0.4 fps/ft at the point of capture velocity (7 fps). Guidance from Conte lab work show gradients less than 1.0 fps/ft ok	9.5	12.5		9.2%	Fixed hydroacoustic & radio tag					
Lower Granite RSW	Almota, WA	on the	Snake River	Existing	Linear	Critical	Surface Spill	Gradual Symmetrical Approach	No	Yes, rounded, gradually shaped side piers and floor approach	No	Spillway Ogee	Rectangular	Supercritical	Varies	7000	Deflected spillway jet	All Three	100	120	0.21	None	1	70.17	48.00	25.75	16.00	12.875	1806.98	7,000	100	130,000	No	3.9	9.1	0.32	5.4%	Fixed hydroacoustic, radio tag, balloon tag, acoustic tag		0.49	0.44	9.10	8.17
Lower Granite SBC	Almota, WA	on the	Snake River	Inactive	Linear	Subcritical	Forebay Collector	None	Yes, 4' deep trash boom	No	No	Open Channel	Rectangular	Supercritical	Varies	3500	No	All Three	100	130	0.22	None	1	16.00	16.00	28.00	28.00	8	448	3,500	219	130,000	No	7.8	n.a.	0.80	2.7%	Hydroacoustic, radiotelemetry		0.32		11.70	0.00
Lower Monumental RSW	Kahlotus, WA	on the	Snake River	Under Development	Linear	Critical	Surface Spill	None	No	Yes	No	Spillway Ogee	Rectangular	Supercritical	Varies	17000	Deflected spillway jet	All Three	100	120		None	1	63.16	48.00	15.00	15.00	7.5		9,500		108,000	No	10.0	13.2	0.68	8.8%						
Mayfield Louver System	Mayfield, WA	on the	Cowlitz River	Existing	Linear	Subcritical	Forebay Collectors	None	No	No	Yes, Louvers	closed conduit flow	Circular		Plunging	10	No	Field	182	33		Deeply incised river channel (canyon) immediately upstream	2	48.00	48.00	33.00	33.00	16.5		200		13,660	Unknown	0.1	0.1	0.14	1.5%	Acoustic Tag, Balloon Tag					
McNary TSW	Umatilla, OR	on the	Columbia River	Under Development	Linear	Critical	Surface Spill	None	No	Yes	No	Spillway Ogee	Rectangular	Supercritical	Plunging	10000	No	All Three	100	120		None	1	50.00	48.00	15.00	15.00	7.5	750	10,000	200	232,000	No	13.3	13.9	0.30	4.3%	None	Planned for 2008				
North Fork Dam V-Screen Collector (FSC)	Estacada, OR	on the	Clackamas River	Under Development	Cul-de-sac	Subcritical	Forebay Collector	Expected to draw from top 25 ft	Yes, floating curtains to guide fish to collector, and 200 ft x 50 ft barrier net to keep fish from the spillway	Yes	Yes, V-screens	Open Channel	Rectangular	Subcritical	Skimming	8	No	Field	120	130	0.28	None	2	9.00		36.00	36.00	4.5	648	1,000	56	6,000		1.5	1.5		16.7%	Hydroacoustic, Radio tag, Acoustic Tag, PIT Tag	Plan to deploy strobe lights at turbine intakes to reduce entrainment.				
Priest Rapids Sluice	Mattawa, WA	on the	Columbia River	Existing	Linear	Critical	High Flow Sluice	None	No	No	No	Spillway Ogee	Rectangular	Supercritical	Plunging	2000	No	None	78	100	0.09	None	1	20.00	20.00	9.17	9.17	4.58601	183.44	2,000	100	160,000	No	10.9	10.9		1.3%			0.03	0.04	2.65	3.04
Priest Rapids Spillway Bulkhead	Mattawa, WA	on the	Columbia River	Under Development	Linear	Critical	Surface Spill	None	No	Yes, flow fairings at pier noses and radius on the upstream corner of the invert.	No	Spillway Ogee	Rectangular	Supercritical	Variable	16000	No	CFD, Physical Model	78	100		None	2	40.00	40.00	13.50	13.50	6.75	1080	16,000	200	160,000	No	14.8	14.8		10.0%		Planned for 2008				
Rock Island Notched Spill Gates	Rock Island, WA	on the	Columbia River	Existing	Split by Island	Critical	Surface Spill	None	No	No	No	Spillway Ogee	Rectangular	Supercritical	Plunging	1000	No	Physical Model				Sill and Islands						0				220,000	No				0.0%	Fixed or Scanning Hydroacoustic, Radio Tag, Acoustic Tag	Surface notched gate Flow both over and under gate				
Rock Island Over/under Spill	Rock Island, WA	on the	Columbia River	Existing	Split by Island	Critical	Surface Spill	None	No	No	No	Spillway Ogee	Rectangular	Supercritical	Plunging	1000	No	Physical Model				Sill and Islands						0				220,000	No				0.0%	Fixed or Scanning Hydroacoustic, Radio Tag, Acoustic Tag	Surface notched gate Flow both over and under gate				
Rock Island Overflow spill gate	Rock Island, WA	on the	Columbia River	Existing	Split by Island	Critical	Surface Spill	None	No	No	No	Spillway Ogee	Rectangular	Supercritical	Plunging	1000	No	Physical Model				Sill and Islands		9.00	9.00			4.5				220,000	No				0.0%	Fixed or Scanning Hydroacoustic, Radio Tag, Acoustic Tag	Surface notched gate Flow both over and under gate				
Rocky Reach	Wenatchee, WA	on the	Columbia River	Existing	Z-Dam	Subcritical	Forebay Collector	Eddying that Concentrates Flow/Fish	No	Yes	Yes	Open Channel	circular	Subcritical	Plunging	360	No	All Three	90	105	0.57	None	2	20.00	20.00	60.00	60.00	10	2400	6,000	150	220,000	No	2.5	n.a.	0.55	2.7%	Fixed or Scanning Hydroacoustic, Radio Tag, Acoustic Tag, Didson, PIT tag		0.45	0.25	16.32	9.17
Round Butte SWW Structure	Near Madras, OR	on the	Deschutes River	Under Development	Linear	Subcritical	Forebay Collector	None	No	Yes	Yes	closed conduit flow	circular	Subcritical	n.a.	n.a.	n.a.	All Three	365	260		Deep canyon	2	30.00	30.00	45.00	45.00	15		6,000		14,000	Yes	2.2	2.2		42.9%	20-inch Hidrostal Fish Pump Test, Screen Biofouling Test	Only outlet, Trap and Haul				
The Dalles Ice/Trash Sluice	The Dalles, OR	on the	Columbia River	Existing	Z-Dam	Critical	High Flow Sluice	None	No	No	No	Open Channel	Rectangular	Supercritical	Plunging	4400	No	All Three	85-75	100	0.09	Significant bathymetric relief	6	19.69	19.69	8.87	3.28	4.43352	1047.55	4,400	37	270,000	No	4.2	11.4	0.50	1.6%	All		0.11	0.07	6.99	4.30
Upper Baker Project Floating Surface Collector	Near Concrete, WA	on the	Baker River	Under Development	Linear	Subcritical	Forebay Collector	Upwelling and converging, minor eddying & sweeping flow across face of guide nets	Yes, Guidenets	Yes, impermeabline liner on aluminum lattice frame with narrowing walls and inclined floor between net and gulper	Yes	Open Channel	Rectangular	Subcritical	n.a.	n.a.	n.a.	CFD, Physical model	285	290		Steep canyon with narrowing dog-leg 800' upstream of FSC entrance	1	16.00		16.00	16.00	8	256	500	31	5,050	Yes, max velcoity at NTS is 0.13 ft/s, acceleration increases from 0 to 2 fps/ft, no decelleration	2.0	2.0	0.17	9.9%	Fixed and mobile hydroacoustic, radiotelemetry acoustic tracking, long-term mark-release-recapture, traps data	Trap and Haul				
Upper Baker Project Gulper	Near Concrete, WA	on the	Baker River	Existing	Linear	Subcritical	Forebay Collector	Upwelling and converging, minor eddying & sweeping flow across face of guide nets	Yes, Guidenets	Yes, impermeabline liner on aluminum lattice frame with narrowing walls and inclined floor between net and gulper	Yes	Open Channel	Rectangular	Subcritical	n.a.	n.a.	n.a.	Field	285	290		Steep canyon with narrowing dog-leg 800' upstream of FSC entrance	1	16.00		6.50	6.50	3.25	104	500	31	5,050	No	4.8	4.8	0.49	9.9%	Fixed and mobile hydroacoustic, radiotelemetry acoustic tracking, long-term mark-release-recapture, traps data	Trap and Haul				
Wanapum Future Units Bypass	Near Beverly, WA	on the	Columbia River	Under Development	Z-dam	Critical	Surface Spill	None	No	Yes, large pier noses, radius on invert and radii on intake corners.	No	Spillway Ogee	Rectangular	Supercritical	Skimming	20000	No	All Three	80	110		None	1	18.50	18.50	77.00	77.00	9.25		20,000		160,000	No	14.0	14.0	0.05	12.5%		For fish only				
Wanapum Prototype SC	Near Beverly, WA	on the	Columbia River	Inactive	Z-dam	Subcritical	Powerhouse Retrofit	None	No	No	Yes	Open Channel	Rect. To Circ.	Supercritical	Plunging	50+	No		80	110	0.45	None	1	16.00	16.00	50.00	50.00	8	800	1,400	88	118,304	No	1.8	n.a.		1.2%	Hydroacoustic		0.003	0.003	0.25	0.25
Wanapum Sluice	Near Beverly, WA	on the	Columbia River		Z-dam	Critical	Low-flow Sluice	None	No	No	No	Open Channel	Rectangular	Supercritical	Plunging	50+	No	Physical Model	80	110	0.08	None	1	20.00	20.00	9.17	9.17	4.58601	183.44	2,000	100	118,304		10.9	10.9		1.7%	Hydroacoustic		0.05	0.06	2.72	3.83
Wanapum Spillway Bulkhead	Near Beverly, WA	on the	Columbia River	Inactive	Z-dam	Critical	Surface Spill	None	No	No									80	110	0.58	None	1	50.00	50.00	63.48	30.00	25	3173.96	20,000	400	118,304		6.3	13.3		16.9%	Hydroacoustic, radio tag		0.17		1.00	0.00
Wells Surface bypass	Pateros, WA	on the	Columbia River	Existing	Hydrocombine	Subcritical	Physical Retrofit on Powerhouse	Upwelling	No	No	No	Spillway Ogee	Rectangular	Supercritical	Variable	11000	No	Physical Model	78	140	0.51	Shallow approach bathymetry	5	16.08	16.08	72.00	72.00	8.04	5788.8	11,000	137	220,000	No	1.9	n.a.		5.0%	Fixed hydroacoustic	Deep vertical slot on spillway	0.89	0.89	17.89	17.79

* - For critical flow (weir-type) entrances, depth and velocity are assumed to be the critical values for the design unit discharge.

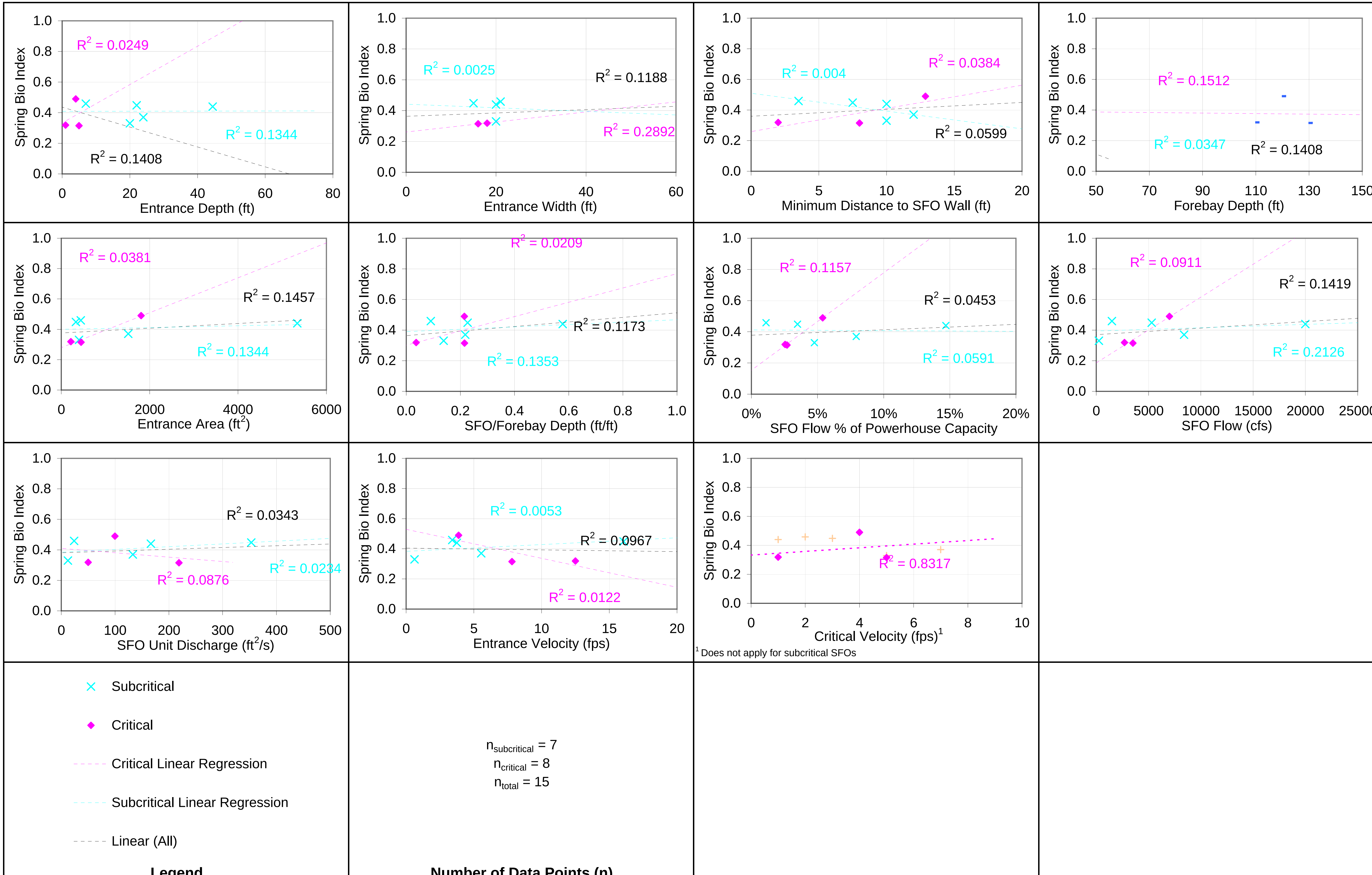


Figure B-1 Correlation Between Physical Parameters and Spring Bio Index

ENSR | AECOM

Appendix C

Detailed Project Descriptions

Appendix C – Table of Contents

Mid-Columbia River

Lower Snake River

Lower Columbia River

Other Pacific Northwest Rivers

Project Description

Project: Wells Surface Bypass

Presenter: ***Rick Klinge (Douglas PUD)***

Completed By: Rick Klinge

Email: rklinge@dcpud.org

Phone: 509-881-2244

Date: November 1, 2006, Revised 1/4/07 GEJ

A) Introduction:

1) *Why was SFO considered?*
   - The dam has a unique hydrocombine design (spillway over the powerhouse) because there was limited bedrock and the channel was narrow and deep where the dam was built.
   - The hydrocombine structure created an opportunity to provide surface-flow through the spillway over the powerhouse.
   - Presettlement Agreement established Fish Guidance Efficiency (FGE) of:
     - Spring migrants 80%
     - Summer migrants 70%
2) *What initial data kick-started the process?*
   - Fyke net studies and hydroacoustic studies in the early 1980's found fish at shallow depths along the spillway. These observations suggested that turbine screens would not likely improve fish guidance. Trials with spill operations and partial barriers were tested. Also a 2-D Model test showed shear lines between turbine entrance and spillways may help guide fish into spillway entrance under varying flow scenarios.
3) *What SFOs were investigated (model or prototype)?*
   - Hydrocombine with partial baffles placed in front of the spill gates were tested and deployed to maximize FCE and survival.

B) SFO Alternative 1 (path to final design or current SFO alternative): Hydrocombine

1) *History of development and testing with the decision path.*
   - Table: Major events in the development of SFB at Wells Dam (from Johnson 1996).

Year	Event
~1978	Observed fish moving through relatively small amount of water at The Dalles Dam sluiceway. Had fruitful discussions with Howard Raymond about the efficacy of small volumes of spill for migrant passage.
1979	Signed FERC settlement agreement (1980-1984), which established the framework for bypass development over that five year period.
1980-83	Determined vertical, horizontal, and diel distributions of smolts immediately upstream of the dam and monitored run timing. Most importantly, showed that fish in the forebay were predominately in the upper part of the water column, above the spill/turbine boundary (21.3 m), and thus would be available to a surface flow bypass.
1981	Performed first scientific quality hydroacoustic study to examine fish distribution and migration timing at Wells Dam.
1983	Installed and tested prototype SFB at Bay 10. Attached plywood to trash racks of down unit to make the first baffles.
1983	Demonstrated proof of concept by showing that fish passed into a surface flow bypass with an overflow baffle.
1983-86	Evaluated the most efficient baffle configuration based on bypass passage rates. Found that underflow and vertical slot were very efficient.
1984	Signed new FERC settlement agreement (1985-1989), which established the framework for bypass development over the next five years, assuming particular

	advances each year.
1984	Took first samples inside a turbine intake with scientific quality hydroacoustic equipment.
1984	Tested a configuration with upwelling in the gate slot between the turbine intake ceiling and bypass spill bay floor.
1985	Directly captured fish using a total water column fyke net array. Established unequivocally the surface flow bypass concept at Wells.
1985	By the end of 1985, the SFB concept was accepted by the fishery and utility parties. Up until this time, turbine intake screens were still an option.
1986	Purchased and installed baffles with removable plates. Made the first vertical slot configuration at Wells.
1986	Using hydroacoustic data, substantiated that spill bays with SFB baffles passed significantly more fish than bays without baffles.
1986	Showed vertical slot very effective.
1986	Showed no effect on bypass passage rates whether adjacent bypass units were operating or not.
1987	Determined that the middle and west sections of the dam passed the most fish in bypass, and thus would be the most effective locations for bypass units.
1987	Decided to go with vertical slot configuration.
1987	Purchased and installed four sets of baffles.
1988	Found that predicting fish passage rates in-turbine difficult because of few fish and variability in numbers.
1989	Purchased and installed fifth and final set of bypass baffles.
1989	Took weekly fyke data from a turbine intake at Wells from April though August (five months).
1989	Continuously sampled at several locations to determine sampling design for total project bypass efficiency evaluation 1990-1992.
1990-92	Evaluated total project bypass efficiency. All five bypass slots and most of 30 turbine intakes were sampled. Largest hydroacoustic study on record. Substantiated the performance of the surface flow bypass at Wells Dam.
1991	FERC issues order approving a new, comprehensive, long-term settlement agreement (1991-2012, not subject to modification prior to 2004) that includes the SFB.

- Johnson et al. (1992) summarized the progression of research for SFO development, from baseline descriptive studies to statistical comparisons of SFO efficiency data under rigorous experimental designs. Their table 2 (p. 227) provides a useful summary of the 13 SFO configurations tested and efficiency data for the prototype SFO for Wells Dam. Their Figure 9 (p. 233) shows the vertical distribution data by species from the total water column fyke net array. These data substantiated the potential for SFO at Wells Dam and resulted in the removal of intake screens as a smolt bypass option.
- A vertical slot configuration was chosen for installation project-wide at every other spill bay across the powerhouse. The 1980-1989 SFO studies at Wells Dam reported by Johnson et al. (1992) led to total project SFO efficiency was the subject of hydroaouctic studies during 1990-1992 (Skalski et al. 1996).
- The SFO at Wells Dam is efficient because it provides an upper water column passage route where the smolts are distributed vertically. Furthermore, the hydrocombine structure also has important effects horizontally as the entire river flow at Wells Dam moves through an area about 300 m wide.

Smolts apparently are not "attracted" by SFO flows as much as they use them to "discover" an acceptable passage route in the upper water column. The SFO at Wells Dam works because it takes advantage of the synergism between the dam's hydrocombine structure and smolt behavior.

2) *What modeling and prototype development was done? Present in timeline format.*
   - A 2-D model was tested to understand the feasibility of altering the inflow pattern between spillways and turbines to prevent juvenile fish from entering the turbines. This was done in 1982, ten years before the bypass was evaluated for FCE and approved by the fisheries agencies and tribes.

C) Present status of facility (routine operation):

1) *Project layout/bypass system configuration: Hydrocombine Design*
   - Hydrocombine structure has 11 spill gates over 10 powerhouse generating units.
   - Flow barriers were placed in front of even numbered spill gate entrances to partially constrict the opening with a vertical slot orientation.
   - Even spill gates for bypass are operated in conjunction with generating units immediately beneath for efficient attraction and passage.
   - Water enters the bypass intakes above water entering the turbine intakes because of Wells' hydrocombine design. The SFO at Wells is based on spill intake baffles that increase flow velocities in the forebay immediately upstream of the baffle opening.
   - The SFO at Wells Dam has five individual bypass units. A bypass unit is formed by modifying a spill bay with sidewalls, gate slot plugs, and baffles. Side walls installed between the pier noses and the turbine pit walls on each side of a spill bay prevent water from flowing between adjacent spill bays, thereby increasing the effect of the intake baffles on forebay flows. Gate slot plugs prevent flow between turbine intakes and the bypass unit. Baffles anchored in the trash rack guides in the bypass intakes increase flow velocity into the bypass units (about 61 cm/sec or 2 fps) above the velocity that would be achieved by the same flow without baffles. The baffle opening can be oriented horizontally or vertically in 1.22-m increments of height or width. The baffles are the most important feature in the design of the SFO at Wells Dam. After many years of testing, a vertical slot baffle opening (4.88 m wide) was selected and is used today.
2) *Cost (Design, Construction, Evaluation)*
   - $3.8 million in testing
   - $1 million spent in barrier screens for each spill gate (5 million total).
3) *Biological performance*
   - Three years of spring and summer fish guidance efficiency trials established (1990 – 1992) the following results (from Skalski et al. 1996; table 5).

Species	Study-Year	Fish Collection Efficiency	Fish Collection Effectiveness
Run-at-Large Spring	1990	0.84	16.9
	1991	0.95	19.0
	1992	0.89	17.8
	mean	0.89	17.9
Run-at-Large Summer	1990	0.77	15.3
	1991	0.97	19.4
	1992	0.93	18.7
	mean	0.89	17.8

   - Project survival estimates (1999-2001)
     - Arithmetic Average - 96.2% (+- 3.0%)
       - 1998 Chinook – 99.7% (+/- 2.9%)
       - 1999 Steelhead – 94.3% (+-3.1%)
       - 2000 Steelhead – 94.6% (+- 2.9%)
4) *Future plans*

- None.

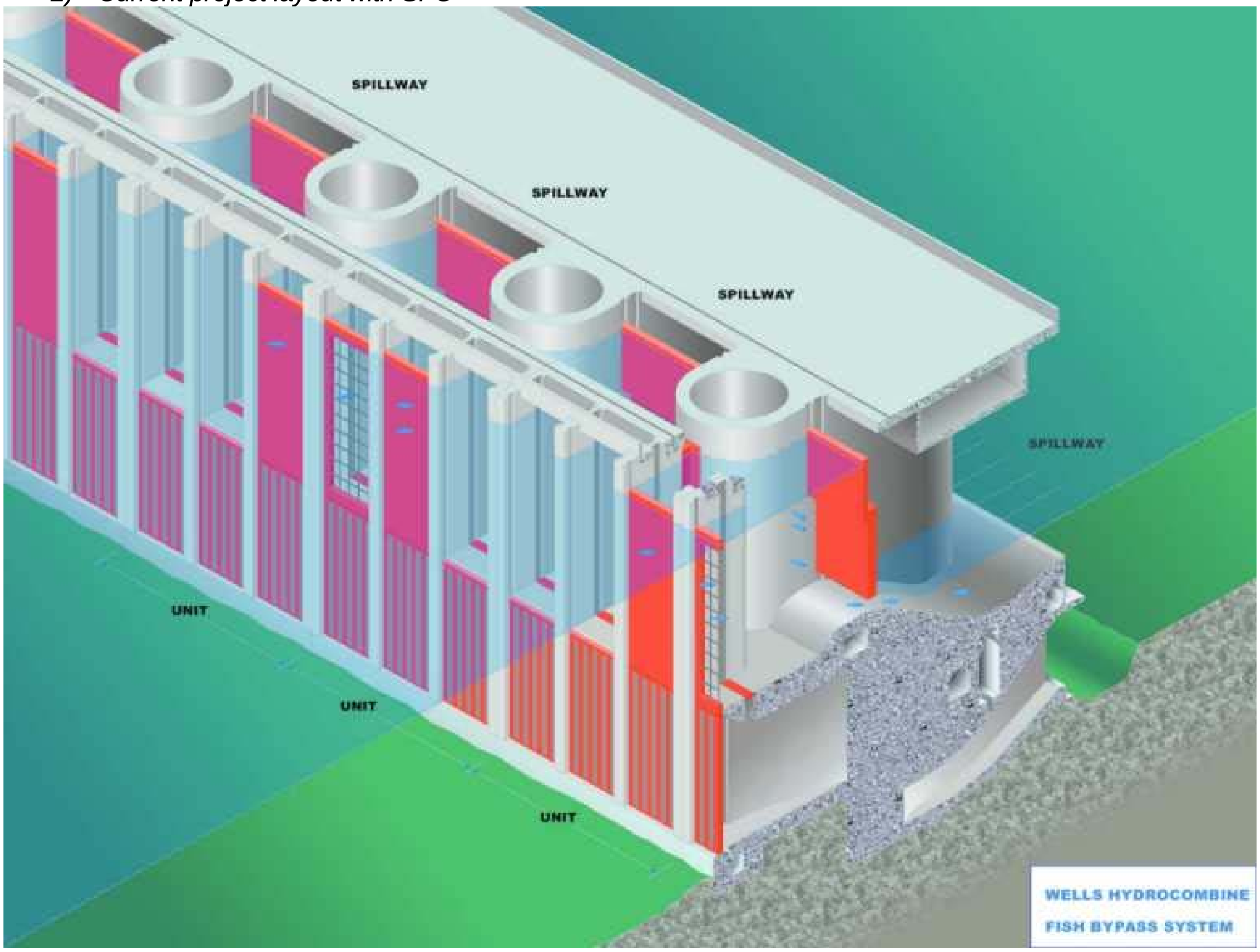
D) Conclusions and lessons learned (from all designs):

1) *Data gaps identified*
   - These studies were performed in the1980's and early 1990's. Evaluation tools used included hydroacoustic studies verified by fyke netting. These studies demonstrated the SFO was able to achieve the performance criterion for both spring and summer migrants. Questions not answered by the evaluation include how fish approach the bypass openings or if they prefer top spill over bottom spill passage through the spill gates. The Wells Juvenile Bypass is effective in bypassing fish and survival through the project plus dam is above the 95% survival standard established under the Habitat Conservation Plan.
2) *Guiding principles/recipes for success*
   - Hydrocombine design
   - Flow baffle development
   - Favorable bathymetry
   - Turbine design may have influenced flow fields to provide efficient bypass
3) *Pit falls, i.e. what not to do*
   - We were fortunate at Wells that the SFO continued to exceed performance expectations. We did not waste time chasing ideas that were marginal or ask why this was not working. It did not matter. We were looking for a solution to effectively guide fish.
4) *Absolute requirements*
   - Involvement and cooperation of all entities
5) *If you had it to do all over again, what would you do differently?*
   - I am not sure we would change anything. The Joint Fisheries Parties allowed the District to reach a solution. We dismissed some of their ideas and sought a unique solution that was as unique as the design of the dam on the Columbia.

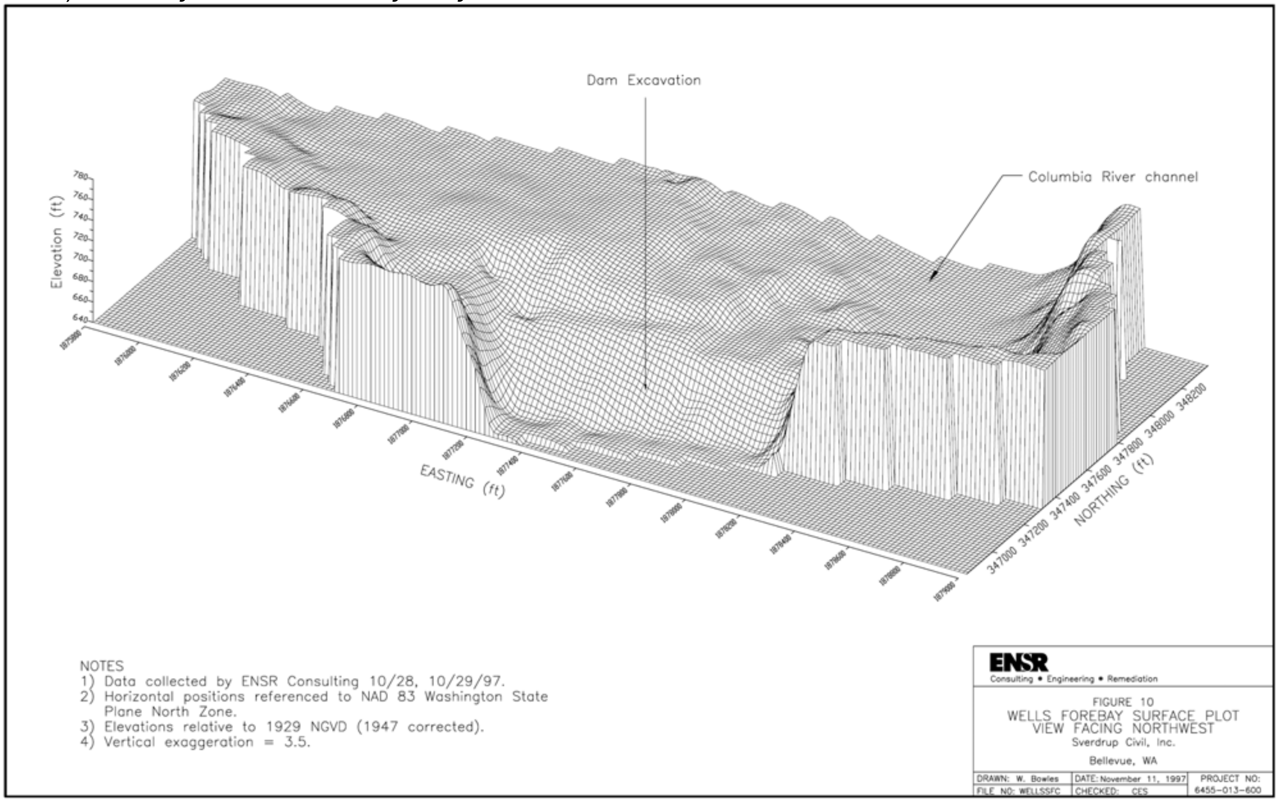
E) Exhibits:

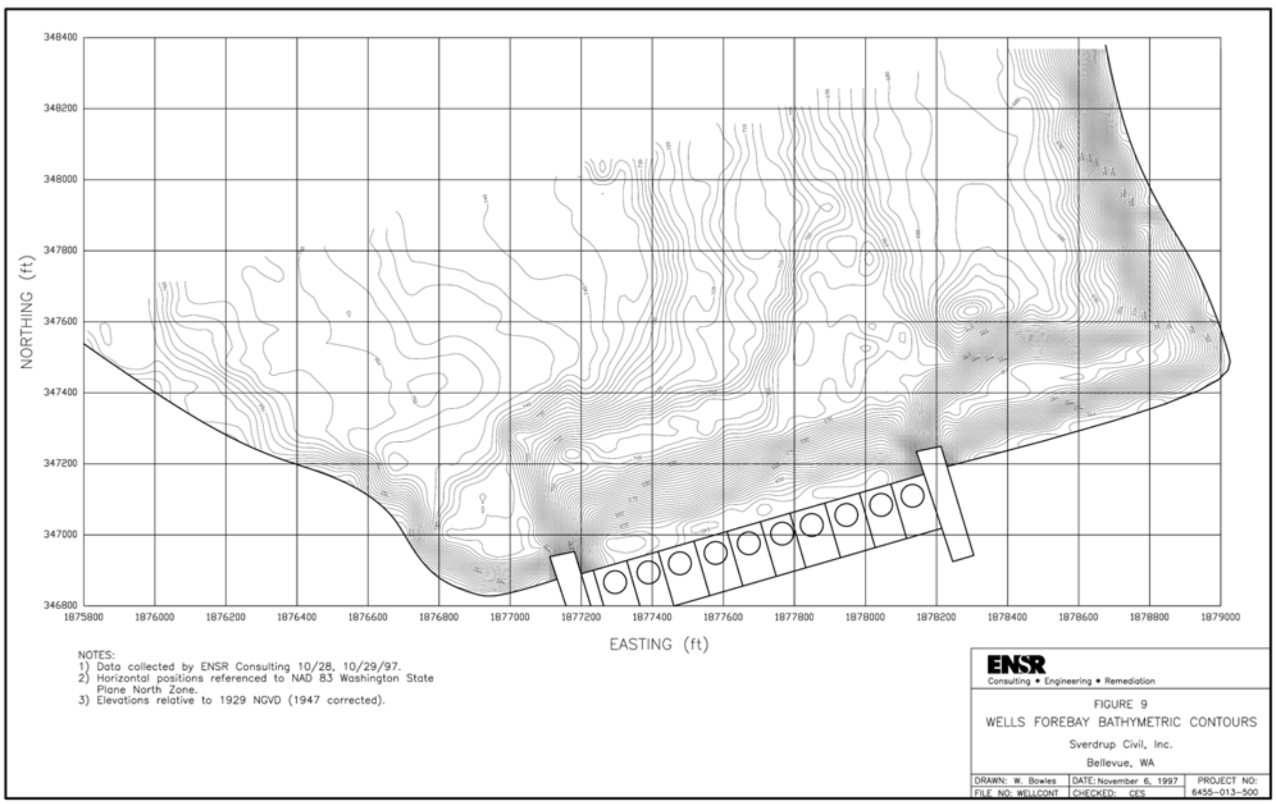
1) *Aerial photo*

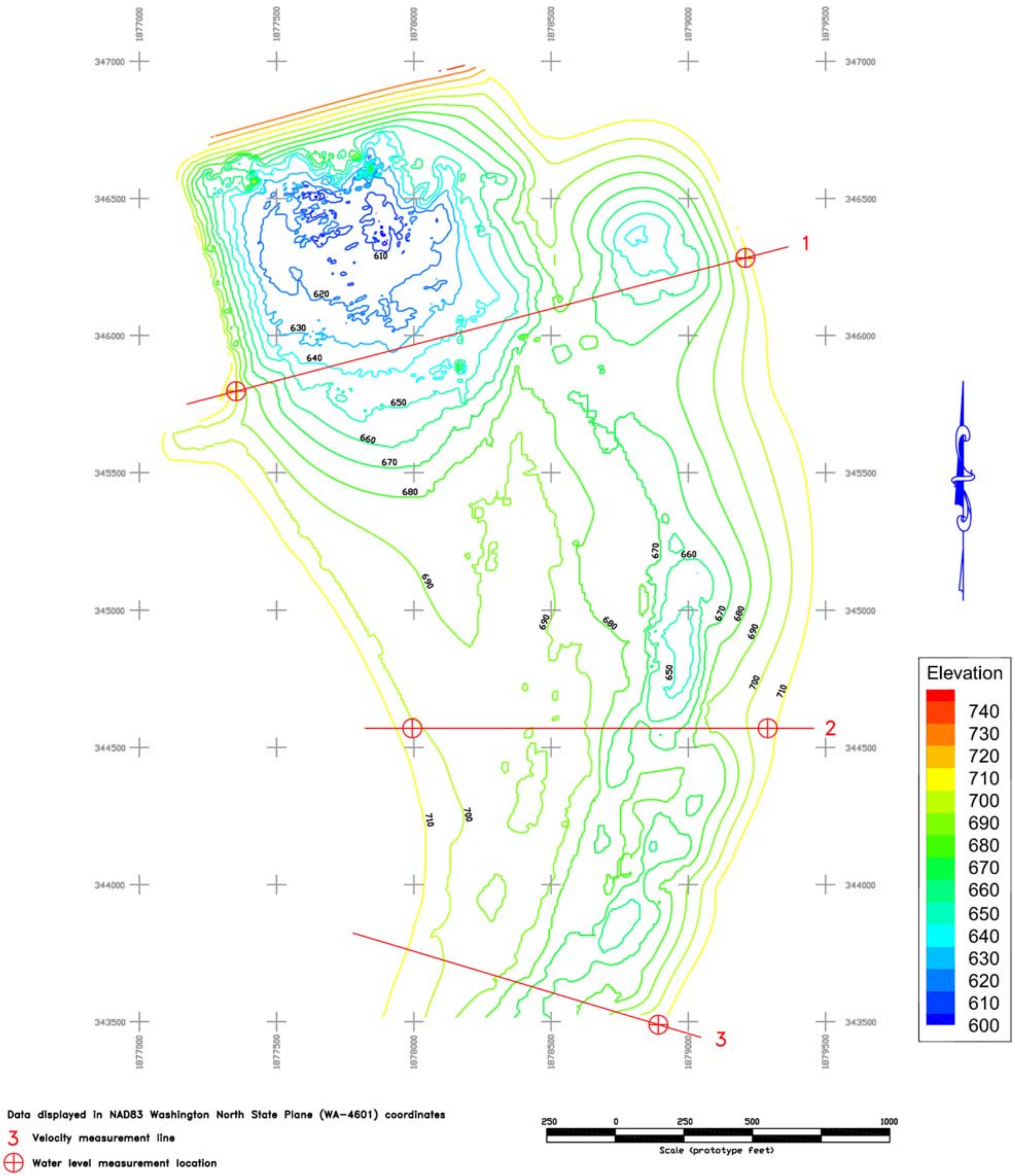
2) Current project layout with SFO



3) *Forebay and tailrace bathymetry*







4) *Current plan and profile of the SFO structure* (not currently available)

5) *Forebay & tailrace flow fields* (not currently available)

Project Description

Project: Rocky Reach Surface Bypass

Presenter: ***Chuck Peven***

Completed By: Duncan Hay
Email: duncanhay@shaw.ca
Phone:604-936-5161
Date: February 14, 2007

F) Introduction:

1) *Why was SFO considered?*
   - To achieve the goals set out in Settlement Agreements of the 1980's and subsequently the 2002 Habitat Conservation Plan
   - Low guidance from submersible traveling screen (1985-1988) and bar screen deflectors (1989-1994) for fish bypass (Truscott and Hays 1989; Peven and Abbot 1994).
   - Spill only passed 20% of fish at nearly 50% spill volume.
2) *What initial data kick-started the process?*
   - Hydroacoustic and fyke net studies showed that fish passing the dam were concentrated at the south end of the powerhouse. Over 70 % of juvenile salmonid migrants pass through Units 1 to 3 (Ramehild et al. 1984; Steig and Sullivan 1991).
   - The success of smolt passage at Wells Dam.
   - Hydraulic studies on flow patterns showed the presence of a large eddy in the forebay which contributes to moving fish to the south end of the powerhouse.
   - Diversion screens in Units 1 and 2 showed some success in collecting fish.
3) *What SFOs were investigated (model or prototype)?*
   - A 1500 - 2300 cfs surface collector was initially modeled and prototyped.
   - A 6000 cfs surface collector discharging directly to the tailrace was investigated as a design study.
   - A 6000 cfs surface collector with a pump station and dewatering screens was modeled and prototyped prior to construction of the existing fish bypass.

G) Surface Bypass Direct to Tailrace

1) *History of development and testing with the decision path.*
   - Field studies in the 1980's indicated there was a concentration of smolts in the vicinity southern powerhouse units 1-3. Hydraulic model studies in the mid-1990's indicated this was a feasible location for a surface bypass. A design study was undertaken to assess the feasibility of collecting smolts in a 6000 cfs surface bypass at the southern end of the powerhouse and discharging the fish and flow directly to the tailrace.
2) *Why was the SFO discarded as a design alternative?*
   - A conveyance channel with 6000 cfs to the tailrace from the preferred location of the surface bypass intake, which was far removed from the spillway, was considered impractical in view of other options.

H) Surface Collector with Pump Station and Dewatering Screens

1) *History of development and testing with the decision path*.
   - In 1993 a 1:30 scale hydraulic model of the Rocky Reach forebay was constructed for the purpose of assisting the design development of a surface-oriented bypass (ENSR 1995).
   - In 1994 a prototype was designed and construction commenced in the fall for testing in 1995 (Peven and Abbott 1994). The prototype consisted of a single bypass opening near powerhouse unit 1 that was 15-ft wide and 56 ft deep designed to draw 1500 to 2000 cfs from the forebay. The bypass entrance flow was dewatered to 20 cfs which carried fish in a conduit to an evaluation facility and then the tailrace. Diversion screens remained in place from earlier testing in powerhouse unit 1. About 900,000 fish were estimated by video counts to be bypassed through the prototype (Peven et al., 1995)
   - Modifications were made to the prototype and evaluated during 1995, 1996 and 1997 (Peven et al. 1995; Peven et al. 1996). Modifications made and tested included walls, floors, increasing the entrance flow, narrowing the entrance to increase velocities and installing a weir and transport

system for fish routed to the gatewells in powerhouse units 1 and 2. Starting in 1996 steps were taken to measure fish passage efficiency through the use of PIT tags and radio tags. (Steig and Adenity 1996; Stevenson et al. 1997).The collection efficiency of the system in 1997 was 45% for steelhead and chinook and 14 % for sockeye (Peven and Mosey 1998). Hydroacoustic evaluations of the behavior of fish approaching the powerhouse were also undertaken (Adeniyi et al. 1998).

- A 1:12 scale hydraulic model of the dewatering screens and a 1:2.84 scale model of the gatewell weirs were used in conjunction with the 1:30 scale model for design development of the 1996 and 1997 prototypes.
- In 1997 tests were conducted to evaluate the difference in fish passage performance between a 15-ft wide (low velocity) and a narrower 6-ft wide (high velocity) entrance to the bypass. This evaluation was continued in 1998.
- In 1998, with the benefit of the field and model studies, the prototype was modified to: include a second bypass entrance (SC2) in front of Unit 4; increase the width of the bypass entrance near Unit 1 from 15 to 18 ft; increase the bypass flows to 2500 - 3000 cfs for each entrance through the use of submersible pumps; and add intake diversion screens and gatewell collection in powerhouse unit 2. Entrances were designed to be more streamlined than in previous years. The new second entrance was 7-ft wide to give an entrance velocity of about 7.5 fps, compared to about 3 fps at the other entrance. The development of the 1998 prototype was aided by using three models constructed and tested for earlier work (ENSR 1998a) together with full scale laboratory tests to determine the cause and cure for vibrations in the primary dewatering screens. The 1:100 scale model of the tailrace was also used to examine potential sites for an outfall and collect some of the hydraulic data required for engineering design (ENSR 1998b).
- Evaluations in 1998 were undertaken using hydroacoustics (Adeniyi and Steig 1999), radio tags (English et al. 1998), PIT tags (Mosey et al., 1999), video monitors and a pilot study was undertaken using acoustic tags (Steig et al. 1999). The fish guidance by diversion screens in units 1 and 2 was 73% and 69 % respectively. There was a higher encounter and entrance efficiency of yearling chinook, steelhead and sockeye at the wider entrance located near unit 1. Although there was not statistical difference between the wider and narrower entrances, the trend was that yearling chinook and steelhead had higher guidance with the wider entrance while sockeye and subyearling chinook had slightly higher guidance with the narrow entrance. There was flow separation and upwelling noticed at the narrow entrance of SC2 that may have adversely impacted narrower second entrance.
- In 1999 an articulated wall was constructed at the SC2 entrance to test a 19 ft wide and 35 ft wide entrance each drawing 3300 cfs when set in position for the test. Each entrance was 57 ft deep. There were minor modifications to the diversion screens and bulkheads were installed in all three bays of powerhouse unit 4 to block generating unit intake flow down to elevation 629 ft with the aim of reducing the passage of fish through unit 4. (Mosey et al. 2000). A 1:14 scale model was constructed and tested to develop the diversion screen backing-plate porosities and evaluate the effect of the venture gate position used to draw flow into the prototype fish bypass entrance. The passage efficiency through the bypass system increased and was higher than any of the other years tested being 50.6 % for Chinook salmon, 61.3% for steelhead, 29.4% for sockeye and 39.3% for sub-yearling Chinook. (English et al. 1999 and Steig and Timko 2000). There were no definitive benefits of a wider versus narrow opening for SC2 or the installation of bulkheads at unit 4.
- The prototype configuration of 1999 was left unaltered in 2000 and verified the 1999 biological results with the exception that is was concluded there were no fish passage benefits derived from the bulkheads placed at the intakes to powerhouse unit 4 (Murphy et al 2001). The bypass entrance nearest powerhouse unit 1 consistently bypassed more fish than the entrance near unit 4. Engineering studies of the bypass outfall system were initiated in 2000 (CH2M Hill 2000)and a prototype test of survival of juvenile chinook released in a flow of 420 cfs at 49 ft/s into a tailrace was conducted with 100% survival (Normandeau and Skalski 2000).
- The prototype fish bypass system remained unaltered during the drought year of 2001 and guided more smolts than in any previous year of testing (Murphy, L. J. and Mosey, T. R. 2002). Comparisons between using PIT and acoustic tags that were initiated in earlier years continued in 2001 which eventually led to the conclusion that acoustic tags were as a reliable as PIT tags in determining passage percentages and survivals. Engineering design of a production fish passage

system was essentially completed in 2001 (CH2M Hill 2001) supported by a number of hydraulic model studies (NHC 2001; UWRL 2001; and IIHR 2001a and 2001b).
- Construction of the permanent fish bypass system began in the spring of 2002 and the facility was operational in April of 2003 (CH2M Hill 2003).

I) Present status of facility:

1) Project layout/bypass system configuration: Surface Collector

- The fish bypass system consists of a single bypass entrance 40 ft wide and 57 ft deep located near powerhouse unit 1plus diversion screens and gatewell collection in powerhouse units 1 and 2. Fish entering the bypass and gatewells of units 1 and 2 are transported by a common conduit past an evaluation station to an outfall on the right bank of the river downstream of the dam. Approximately 6000 cfs is drawn into the bypass entrance by a bank of submersible pumps. This flow is dewatered by screens to a flow of 240 cfs and then combined with a flow of 120 cfs from the gate wells for transport of the fish to the tailrace of the project. A guide wall extends upstream of the entrance along the face of the powerhouse to unit 4 with the system being designed to add a second entrance at this location if deemed necessary. Roof seals were constructed under the guide wall into the intakes on units 1 and 2 to facilitate fish passage and reduce head losses.

2) Cost (Design, Construction, Evaluation)

- The cost of design, construction and initial evaluation of the production facility was approximately $110 million. The cost of studies and prototype evaluations leading up to the design of the production system is estimated at $45 million.

3) Biological performance

- A typical distribution of fish passing Rocky Reach dam is shown below for 2005 as a percent passage by route

	Run-of-River Steelhead	Hatchery Steelhead	Sockeye	Yearling Chinook
Surface Collector	68%	69%	31%	32%
Intake Screens	6%	4%	8%	9%
PH Turbine Units 1&2	6%	5%	15%	13%
PH Turbine Units 3-11	18%	19%	43%	41%
Spill	1%	3%	2%	4%

- A summary of smolt survival studies for the Rocky Reach project is shown below with the standard error of the estimates shown in brackets. The project survival includes both dam passage and pool survival.

Species	Year	Project Survival
Yearling Chinook salmon	2004	0.930 (0.020)
	2005	0.911 (0.018)
Steelhead	2004	0.983 (0.018)
	2005	0.930 (0.013)
	2006	0.960 (0.010)
Sockeye salmon	2004	0.835 (0.021)
	2005	0.892 (0.017)

4) Future plans

- The District plans to investigate ways of improving the survival of yearling Chinook salmon and steelhead while concurrently investigating means of improving efficiency and reducing costs.

J) Conclusions and lessons learned (from all designs):

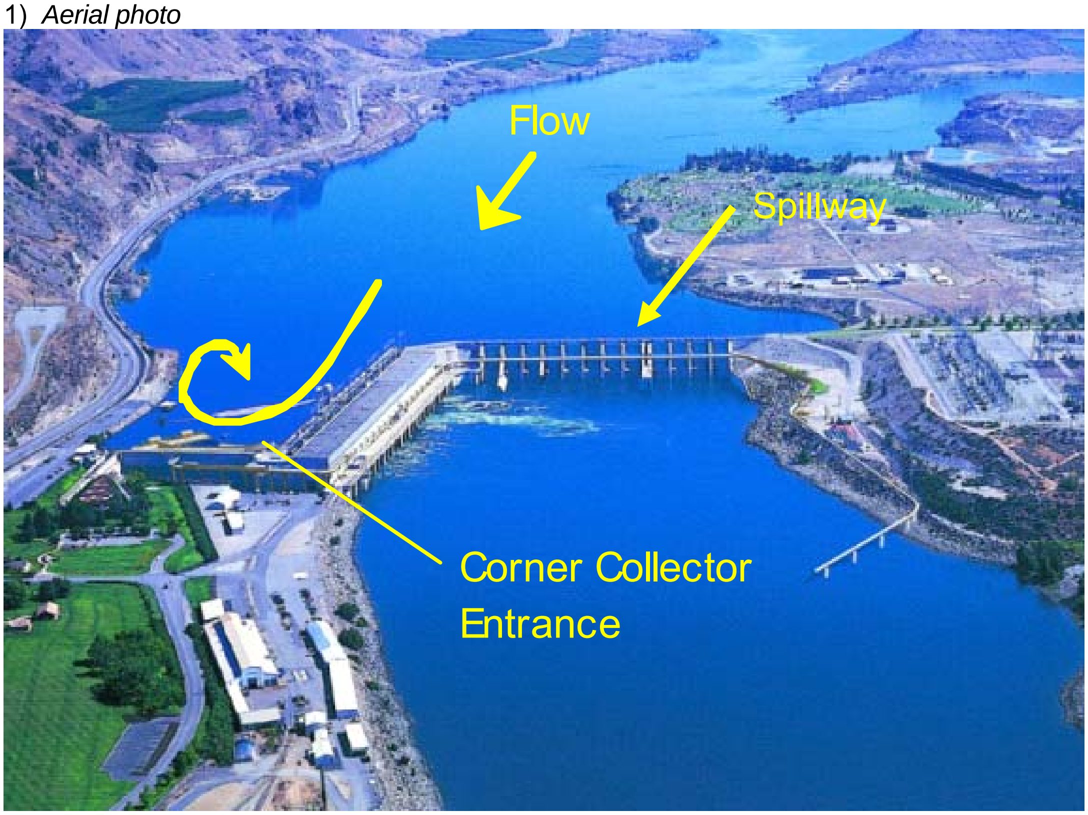
1) Data gaps identified

- Biological performance of sub-yearling Chinook
- Whether behave as a school and, if so, what relevance is that in the design of bypasses.
- Effect of spill on survival at the outfall
- Predation impacts in the immediate vicinity of the powerhouse draft tube portals.
- Effective means of moving sockeye salmon to the shallower water depths in proximity to a surface bypass
- A more rigorous basis upon which to decide an optimum bypass flow giving consideration to effectiveness and economic parameters.

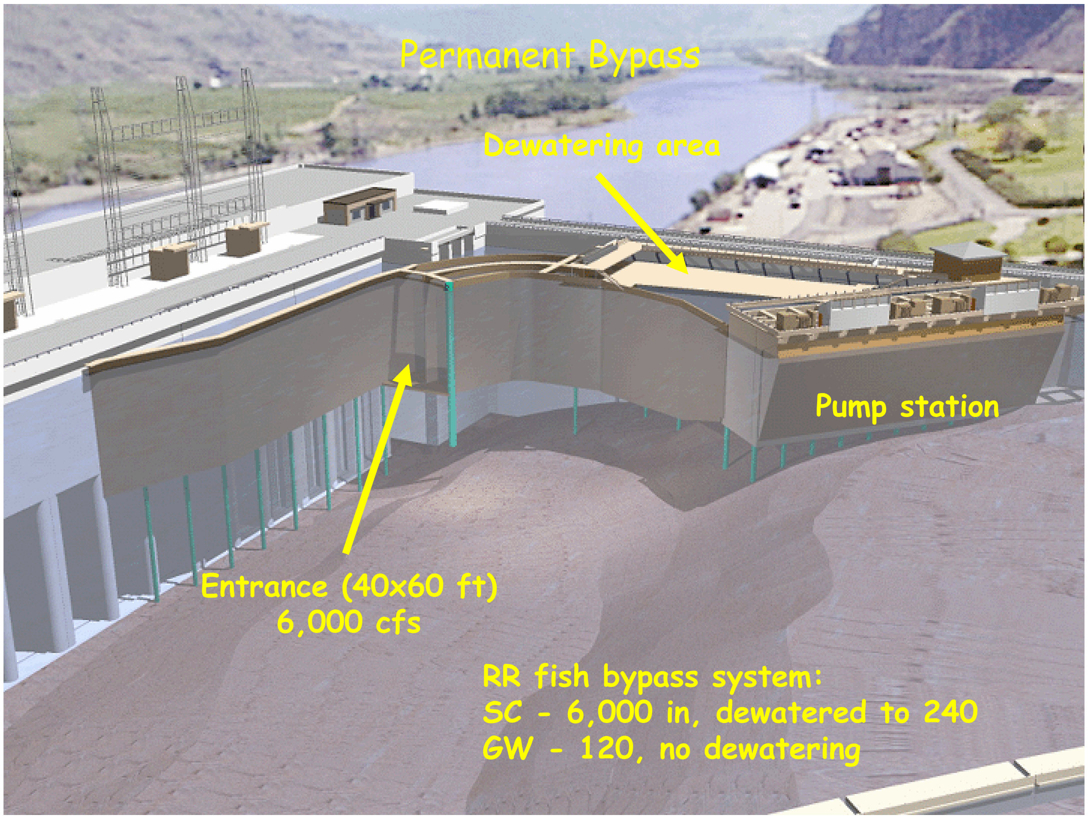
2) *Guiding principles/recipes for success*
   - Design the bypass to fit the unique hydraulic characteristics of the project.
   - Fish appear to prefer a surface oriented route rather than sounding to pass a project.
   - If close to a surface bypass (within 50 ft) a high percentage of fish (>97%) will enter the bypass.
3) *Pit falls, i.e. what not to do*
   - Go to a production system without undertaking prototype tests.
   - Go cheap on prototype tests.
4) *Absolute requirements*
   - Develop and test hypotheses related to the fish behavior as it relates to a bypass concept with due consideration to inter-annual variability in flow conditions and behavioral responses.
   - Test a prototype without any changes to the prototype for more than one year.
5) *If you had it to do all over again, what would you do differently?*
   - Encourage more collective effort in the basin toward getting a more complete understanding of smolt behavior as it relates to characteristics which can be used in the design of bypass systems.

A) Exhibits:

1) *Aerial photo*



2) *Current project layout with SFO*



3) *Forebay and tailrace bathymetry*

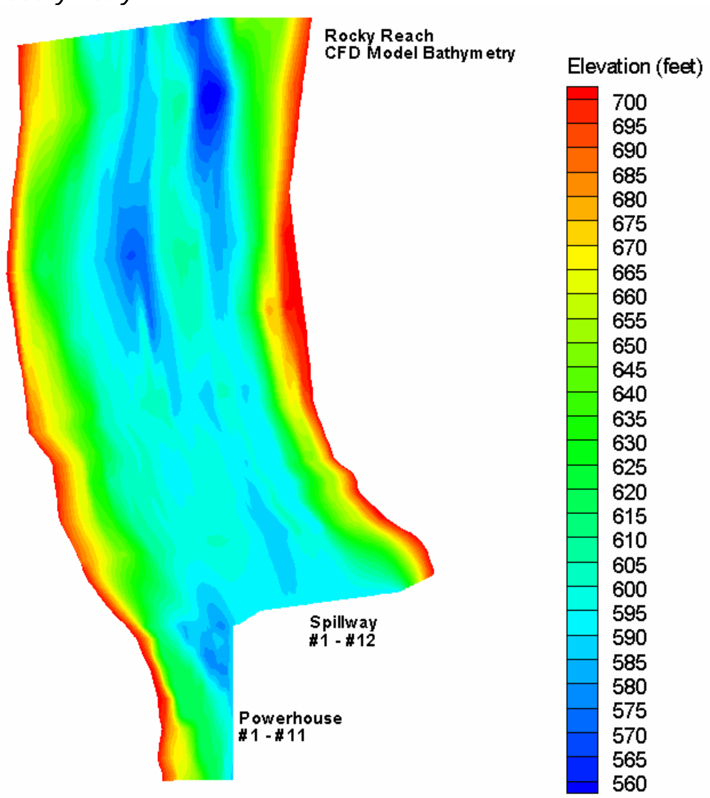
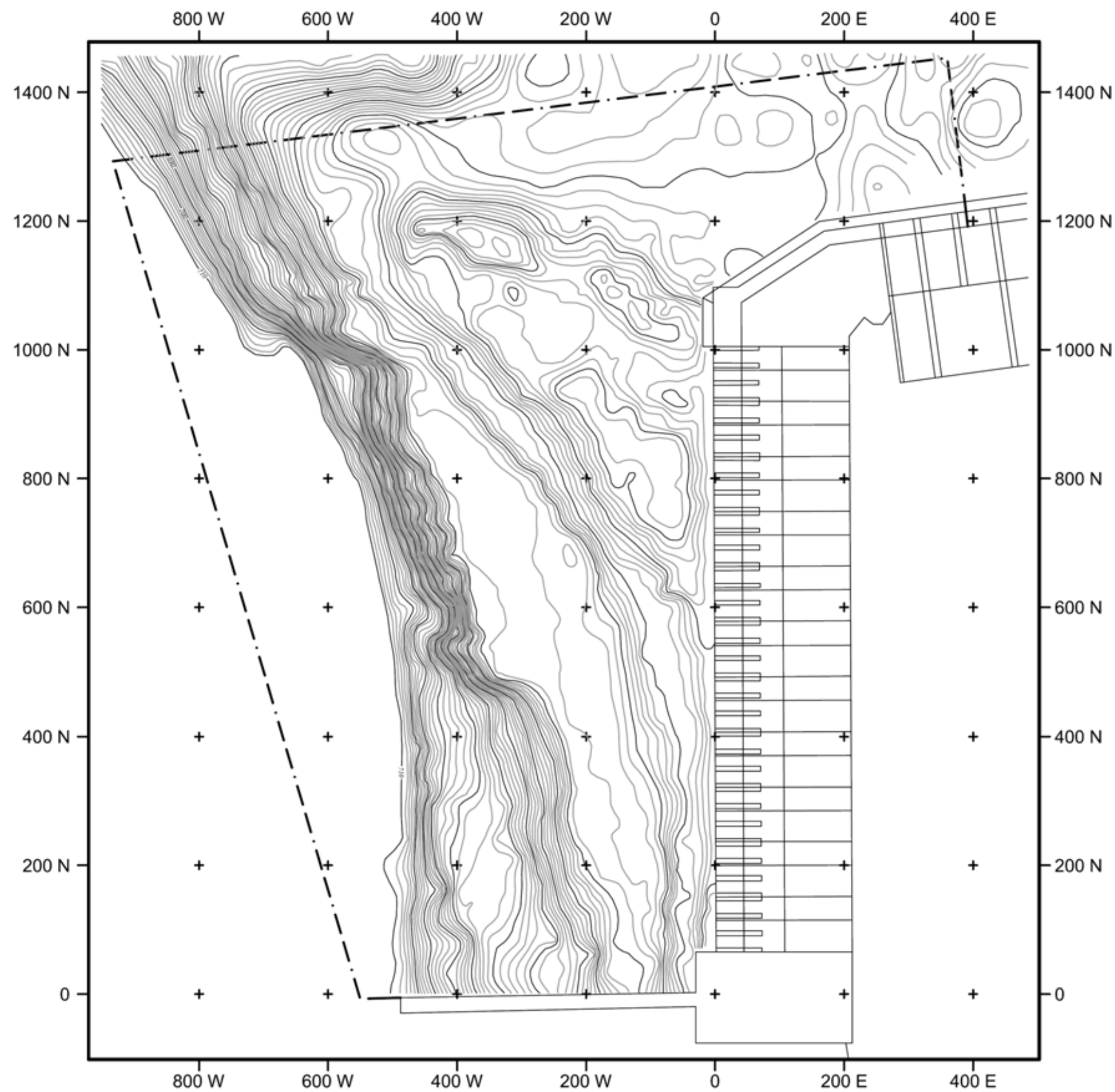


Figure: CFD model bathymetry of Rocky Reach Dam Forebay



Limit of Forebay Model
10-Ft. Countour Interval
2-Ft. Contour Interval

250 150 50
200 100 0 250
Scale in Feet

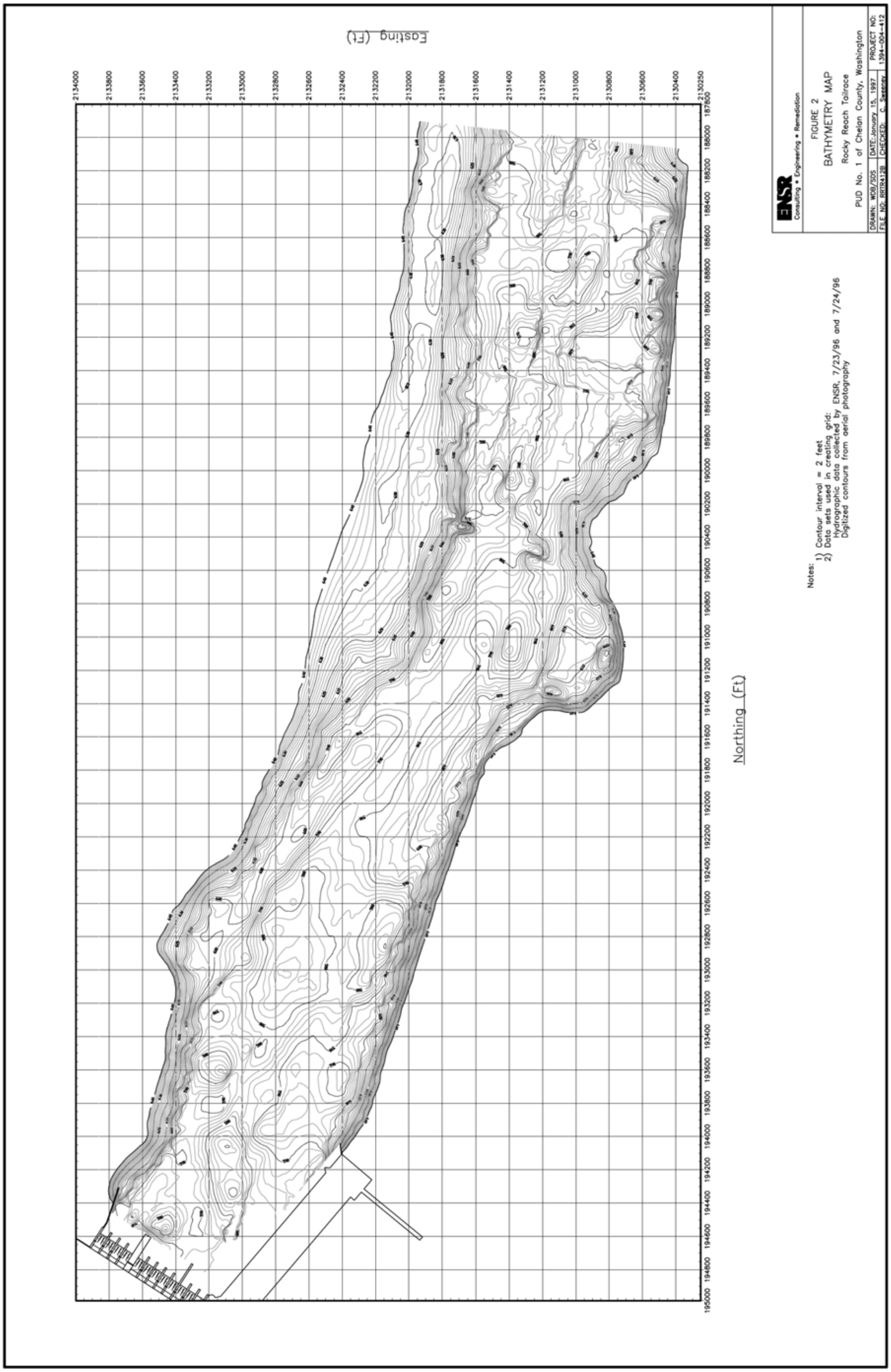
Notes:
1) Contour interval = 2 feet
2) Data sets used in creating grid:
- Hydrographic survey data collected by ENSR
- Digitized contours from site map based on aerial photography of April, 1980.
- Data collected by divers in front of Units 1 and 2
- Intake invert elevations at front of Units 2-10

ENSR
Consulting • Engineering • Remediation

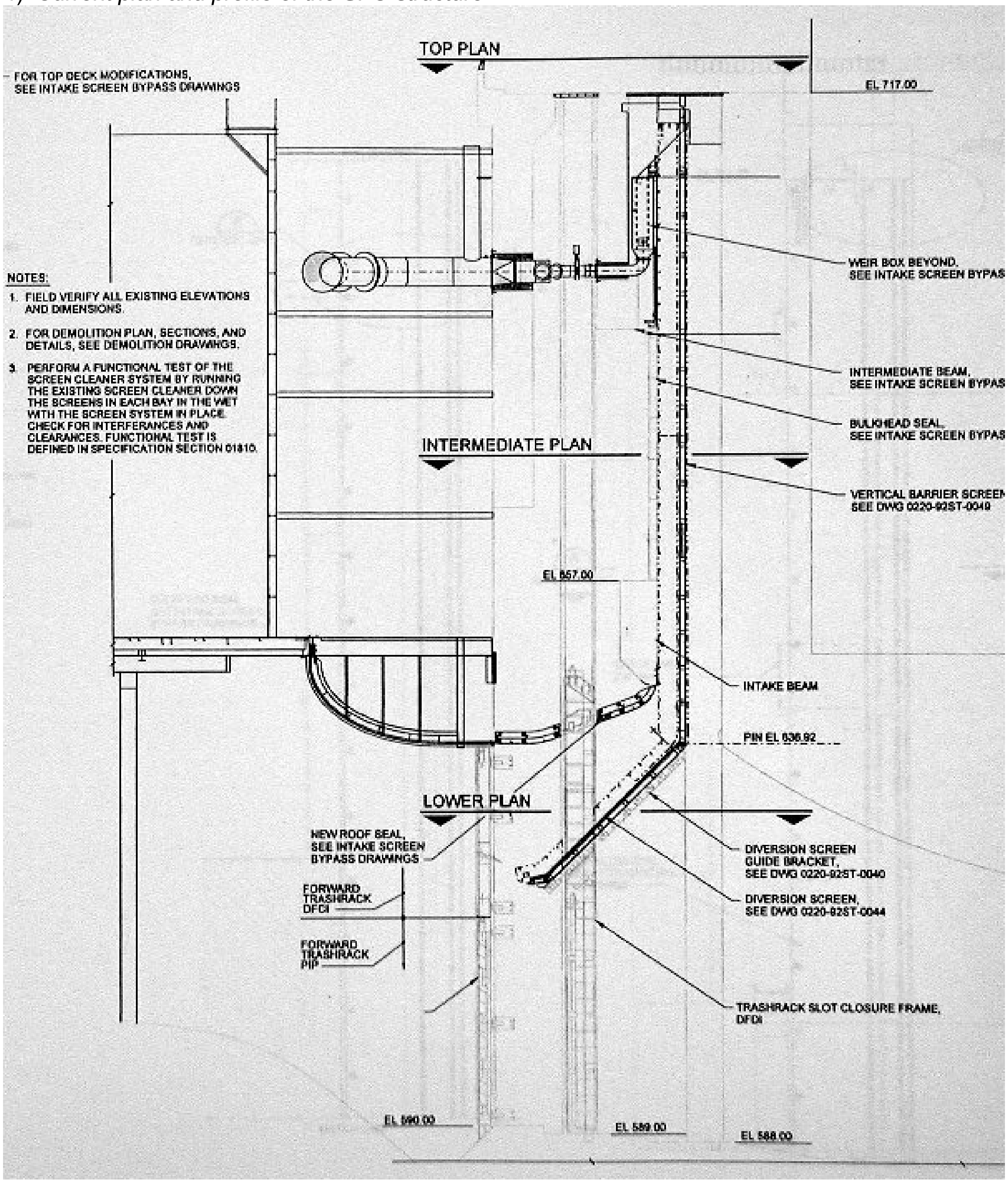
DRAWN:	K. Mongar
CHECKED:	C. Sweeney
DATE:	May 15, 2000
FILENAME:	RR11505A

PROJECT NO: 1394–011–505

FIGURE x–x
ROCKY REACH DAM FOREBAY
BATHYMETRIC SURVEY
Rocky Reach Dam Juvenile Fish Bypass
Public Utility District No. 1 of Chelan County


Easting (Ft)
Northing (Ft)
Notes:
1) Contour interval = 2 feet
2) Data sets used in creating grid:
Hydrographic data collected by ENSR, 7/23/96 and 7/24/96
Digitized contours from aerial photography
ENSR
Consulting • Engineering • Remediation
FIGURE 2
BATHYMETRY MAP
Rocky Reach Tailrace
PUD No. 1 of Chelan County, Washington

4) *Current plan and profile of the SFO structure*



5) *Forebay flow fields*

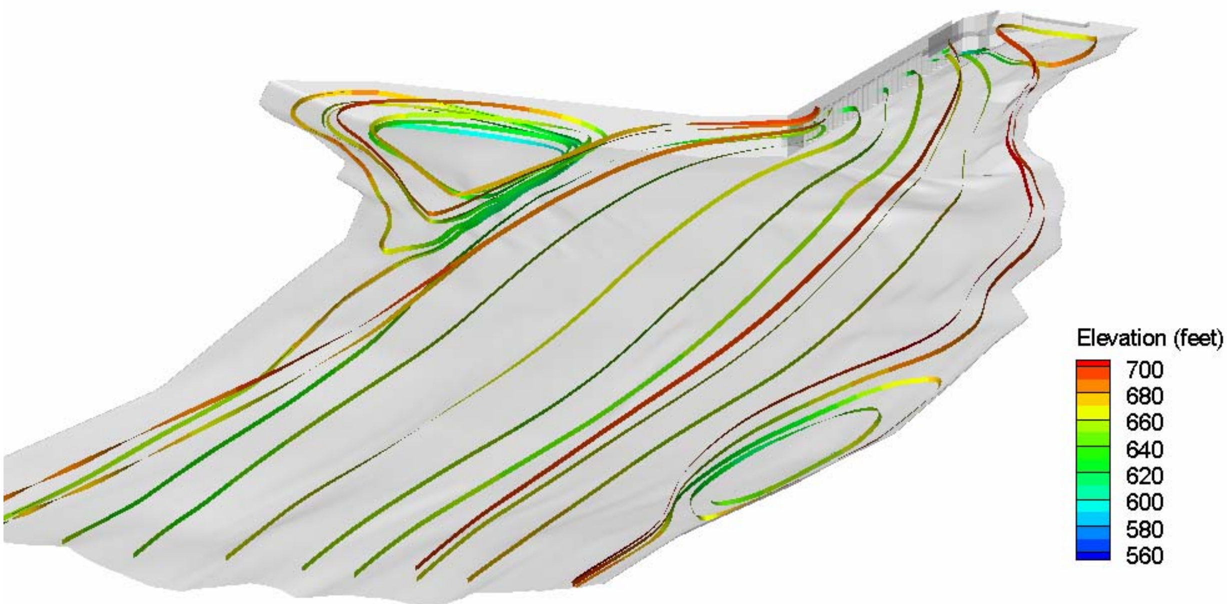


Figure: Streamlines in isometric view colored by vertical distance. Simulation to compare against 1999 Field Data. Total river flow rate: 174.86 kcfs.

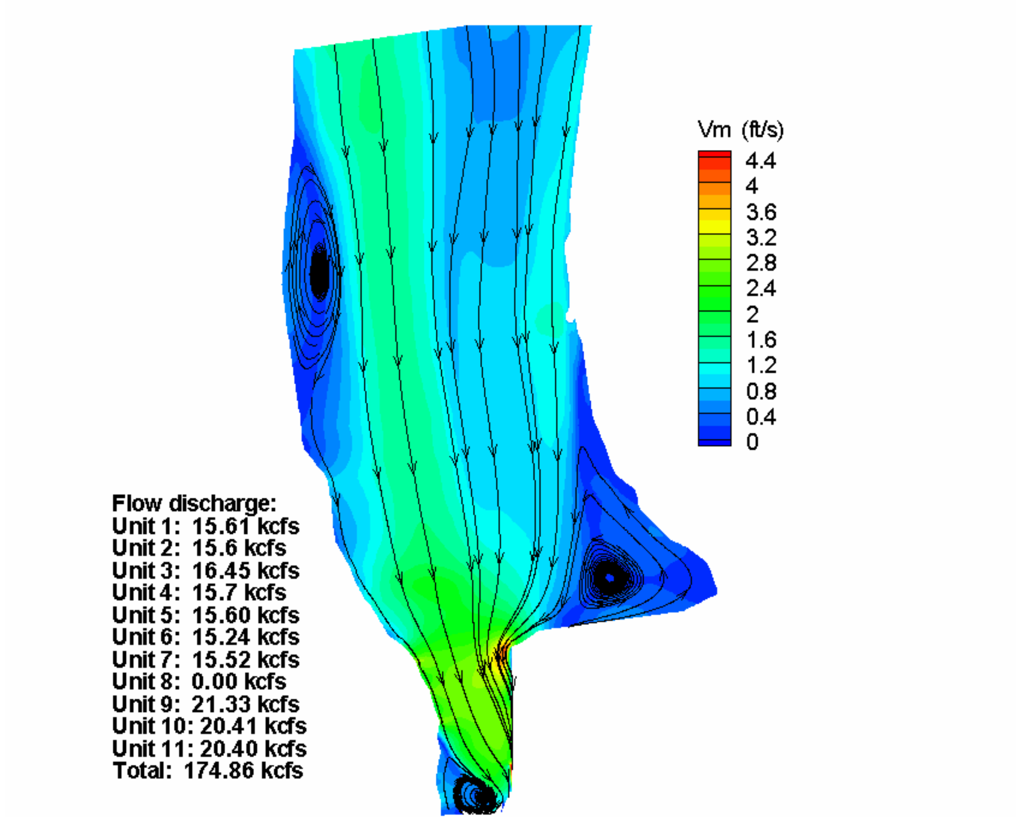


Figure: Streamlines and velocity magnitude contours. Cross section located at a depth of 5 ft. Simulation to compare against 1999 Field Data. Total river flow rate: 174.86 kcfs.

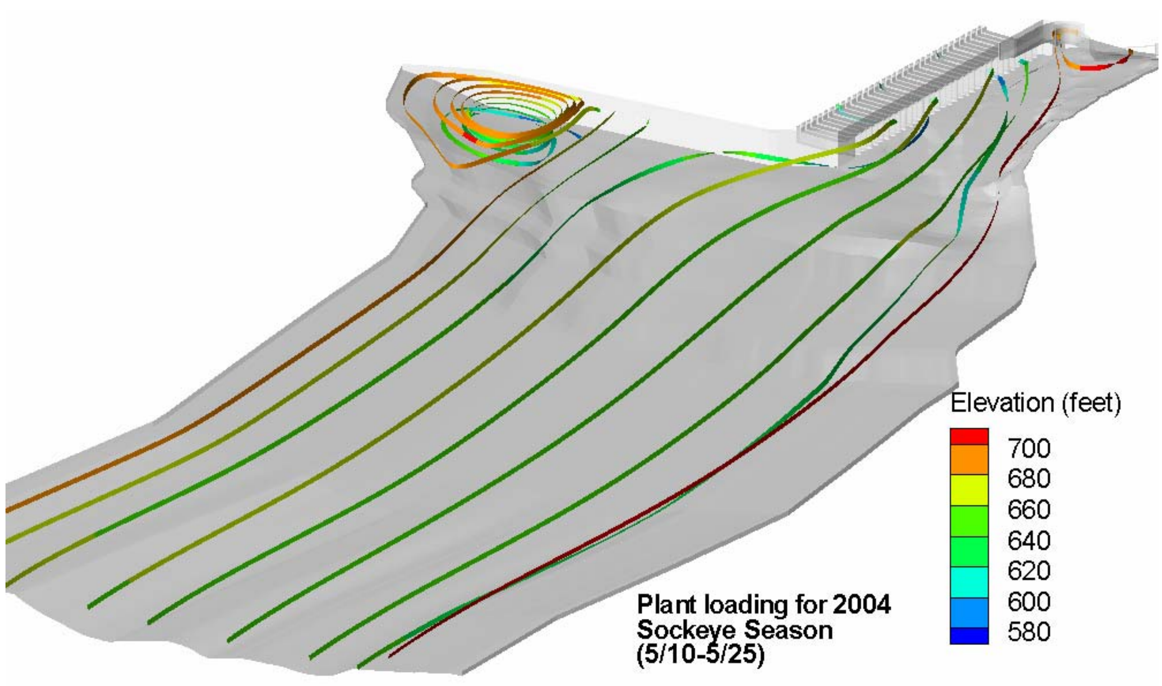


Figure: Streamlines in isometric view colored by vertical distance. Total river flow rate: 120 kcfs.

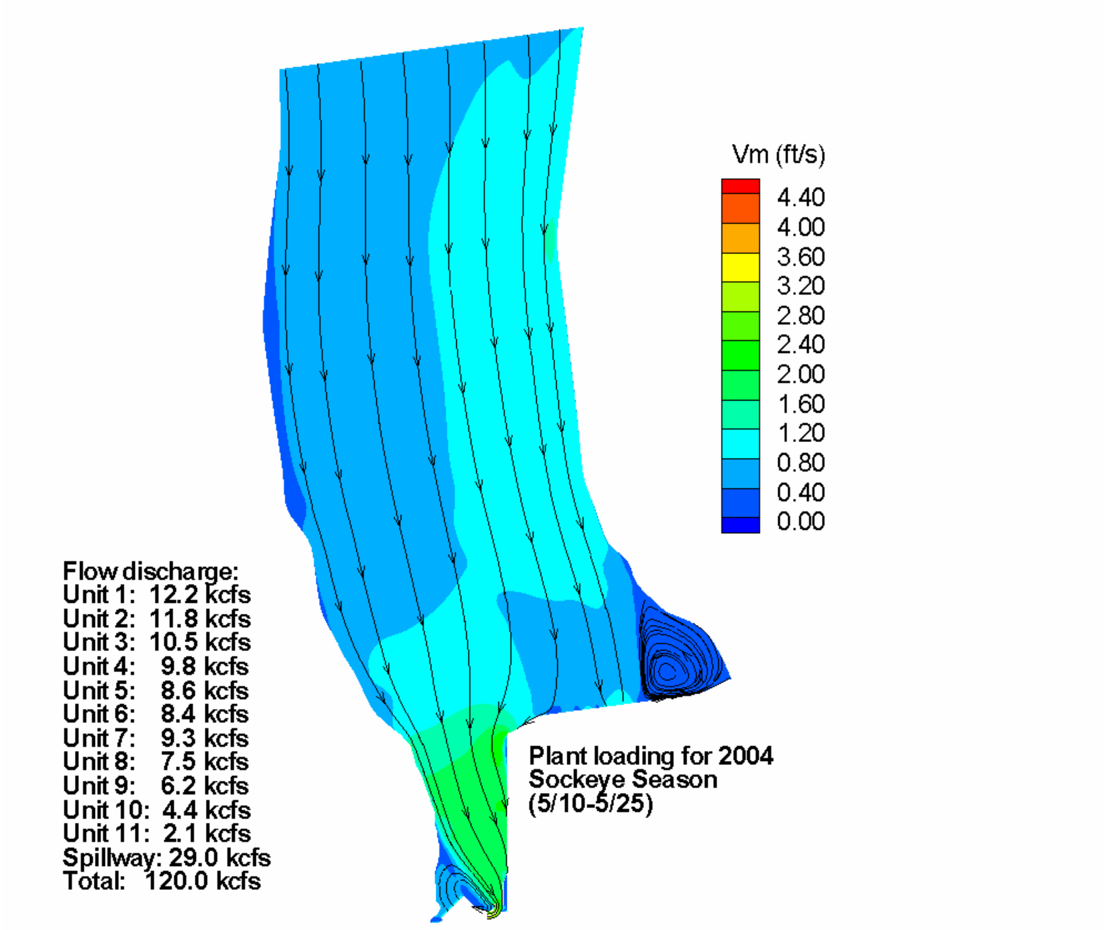


Figure: Streamlines and velocity magnitude contours. Cross section located at a depth of 5 ft. Total river flow rate: 120 kcfs.

Project Description

Project: Rock Island Dam

Presenter: ***Chuck Peven***

Completed By: Duncan Hay

Email: duncanhay@shaw.ca

Phone: 604-936-5161

Date: February 8, 2007

K) Introduction:

1) *Why was SFO considered?*
   - To achieve the goals set out in Settlement Agreements of the 1980's and subsequently the 2002 Habitat Conservation Plan
   - Spill modifications at the project appeared to have more potential as an effective bypass than turbine bypass screen systems.

2) *What initial data kick-started the process?*
   - Fish distribution studies (Gyldenege et al. 1983; Hays 1984; Raemhild et al. 1985) and hydraulic model studies (Mih 1983).
   - Preliminary tests in 1988 of diversion screens upstream of the bulb turbines in Powerhouse 2 raised concerns about the feasibility of screening these units (Fielder 1989; Elder and Weitkamp 1990)
   - Preliminary designs and model testing for diversion screens in Powerhouse 1 indicated that existing piers would need to be moved upstream in order to build a roof upstream of the scroll case to contain and divert the fish (Odgaard 1992). While the percent guidance by screens appeared to be promising additional work would have been required to reduce the impingement of sockeye and sub-yearling chinook (Peven and McDonald 1994).
   - Field studies indicated that spill was efficient in passing fish with about 70% of the fish being passed when spilling about 50% of the flow.
   - There was no statistical difference in the survival of balloon-tagged hatchery-reared chinook smolts through the traditional Kaplan turbines of Powerhouse 1 and the bulb turbines of Powerhouse 2 (Normandeau and Skalski 1997)

3) *What SFOs were investigated (model or prototype)?*
   - Top spill using existing gates and modified (notched) gates was modeled and prototyped.
   - Over/under gates that replaced some top spill gates were modeled and prototyped.

L) Top Spill Gates

1) *History of development and testing with the decision path.*
   - The spillway consists of 31 spillbays, each with one of the two configurations where the elevation of the spillway sills is at 581.5 or 559.0 ft. Each spillbay is 30 ft wide. Downstream of most spillbays there is a concrete apron. The elevation and length of each apron varies considerably over the length of the spillway. The normal forebay elevation is 614.1 ft and the average tailwater elevation during the spring outmigration is 573.0 ft.

   - Spillway gates are comprised of vertical leafs, each leaf being either 11.00 ft or 22.67 ft in height. The low sill bays use two large and one small leaf whereas the higher sill bays use one large and one small leaf. Flow may be released from underneath the gates but is more commonly released by removing upper leafs. There are two sets of gate slots in each bay.

   - Four topspill configurations have been used and tested at Rock Island Dam with design development involving hydraulic modeling and field testing. Minimizing the uptake of dissolved gas during spill was an important factor in design development and testing.

- Through the HCP process, Chelan County PUD spills 20% of the river flow for the spring and summer outmigrants. The 'standard' topspill configuration is to remove an 11.00 ft high leaf from a spillbay which yields a flow of about 10,000 cfs over the top of the remaining gate. Preference is given to using this standard spill configuration in shallow bays in order to minimize the uptake of dissolved gas.

- In 1996, the Chelan County PUD started developing and testing various topspill configurations for Rock Island Dam with the aim of increasing fish passage efficiency and fish survival while reducing the amount of water spilled. A comparison of fish passage was made between two topspill configurations each passing about 1,900 cfs; a 30-ft wide and a 10.25-ft wide opening notched into existing gates, with the narrower opening being deeper to draw the same flow. Laboratory tests in conjunction with kinematic modeling indicated the narrower and deeper opening had a larger zone of influence in the forebay and also drew flow from deeper depths. A 1:64 scale physical model was also used to select spillbays for topspill gates. Hydroacoustic studies indicated that the narrower opening passed more fish per cfs than the wider opening (Iverson et al 1996).

- In 1997 six 9-ft wide topspill openings were constructed for fish passage by modifying existing gate leafs, as was done previously, to host separate centrally located gates, referred to as 'notched gates'. The design flow for these gates was nominally 2,500 cfs. Hydroacoustic studies in 1997 indicated the 9-ft wide gates passed an average of 44.8 fish per unit of flow as compared to 9.6 for the 10.25 ft gates and 16.2 for a 30 ft opening passing 10 Kcfs (Iverson et al 1997).

- In 1998/99 model tests and analytical studies were undertaken to evaluate nappe characteristics, pressures and impact velocities associated with the 9-ft wide top-spill (Nielsen 1999). The impact velocity on a flat apron decreased from 50 fps to approximately 10 fps as the tailwater depth over the apron increased from 5 to 50 ft.

- In 2000 and 2001 tests were undertaken using deflectors at the ends of the submerged aprons to reduce the uptake of dissolved gas associated with spill from the 9-ft wide notched gates. In 2000 the test was undertaken in spillbay 29 where the depth of submergence above the apron was 16 ft and impact velocity on the apron was 41 fps. In 2001 the test was undertaken in spillbay 16 where the depth of submergence varied from 1.8 to 5.7 ft and the impact velocity on the concrete apron was calculated to vary from 51 to 54 fps. Balloon-tagged hatchery-reared chinook smolts were used to determine direct survival and fish condition associated with passage through these topspills. It was concluded that passage through spillbay 29 was benign to fish: passage through spillbay 16 resulted in a direct survival based upon pooled data of 0.99 (90% CI = 0.982 to 0.998) and 1.5 % injuries (Normandeau Associates and Skalski 2001, 2002). Sensor fish were released by Battelle personnel during the 2001 tests to measure impact, pressures and accelerations associated with topspill (Carlson and Duncan 2002). Indications of the sensor fish striking the apron were seen in releases through spillbay 16.

M) Over/Under Gates

1) *History of development and testing with the decision path*.
   - In 2004 a design referred to as an overflow-underflow gate was developed for testing in 2005. The design objective was to withdraw flow from the surface of the forebay and release it below the tailwater to minimize the uptake of dissolved gas while maintaining the benefits of fish passage associated with surface withdrawals. The design took advantage of the two gate slots in each spillbay such that gate leafs were placed in each slot such that flow passed over the top of gate leafs in the upstream slot and through an opening at the bottom of leafs in the downstream slot. The distance between the upstream and downstream gate leafs was 45 inches. The design discharge was 2,500 cfs. The design was tested and refined utilizing a 1:12 scale physical model (Haug and Odgaard, 2004).

- Direct survival and fish condition were investigated through the release of balloon-tagged chinook smolts and sensor fish. An aerated and non-aerated configuration was tested with the non-aerated configuration being the design condition with the least potential for the uptake of dissolved gas. The 48 hr survival probabilities for the pooled aerated and non-aerated test conditions were 1.00 (90% CI = 0.00) and 0.991 (90% CI = 0.98-1.00) (Normandeau and Skalski 2005).

- Field measurements undertaken in March 2005 indicated that the TDG exchange associated with the over/under gate spill was much smaller than observed for the notched gate spill with or without a deflector on the apron for a deep sill spillbay (USACE 2005).

N) Present status of facility:

1) *Project layout/bypass system configuration:*
   - The bypass configuration that has been used successfully in 2004, 2005 and 2006 to achieve HCP goals is spilling surface water from a number of gates spread across the spillway with about 20% of the total river flow being spilled through a combination of notched, over/under gates and regular gates.
   - There are six notched gate 9-ft wide with a sill elevation of 595.3 ft which pass 2500 cfs at a normal forebay elevation of 613.9 ft and three smaller notched gates that pass about 1850 cfs.. The normal operation is to utilize the nine notched gates first and then add regular spill gates if needed to achieve a target percent spill of the river flow.
   - In 2004 there were 9 notched gates used. They were located in bays 32, 1, 16, 18, 24, 26, 30, 31 and 29 with the order being the order in which they where opened to increase spill. Typically the smaller of the notched gates were deployed in spillbays 18, 24, and 26.
   - In 2005 an over/under gate replaced a notched gate in spillbay 31 and the order of opening was 32, 31, 1, 26, 16, 18, 24, 30, and 29.
   - In 2006 the over/under gate was moved to spillbay 32 and the order of opening was 32, 1, 26, 18, 24, 30, 31, and 29.
   - The sequence of opening standard gates as needed was 20, 17, 19, 22, 25 and 21 for each year.

2) *Cost (Design, Construction, Evaluation)*
   - The approximate cost of design, construction, evaluation and testing associated with the SFO bypasses up to 2006 is ????.

3) *Biological performance*
   - The percent distribution of fish through various routes as determined by hydroacoustic studies is tabulated below for the years 2004, 2005 and 2006

Species	Spillway			Powerhouse 1			Powerhouse 2		
	2004	2005	2006	2004	2005	2006	2004	2005	2006
Sockeye	55.0	29.0	27.9	15.2	3.5	3.8	29.8	70.0	65.4
Yr. Chinook	38.6	34.0		4.3	3.0		57.2	60.0	
Sub. Chinook	37.7	- -		29.1	- -		33.3	- -	
Steelhead	16.7	20.0	32.2	1.8	1.0	14.4	81.6	79.0	53.4

   - The mean project survival for the three years of 2004, 2005 and 2006 based on acoustic tag studies for yearling chinook, steelhead and sockeye were 94.4 %, 94.7 % and 96.6 %. These values exceed the survival standard set by the HCP for these species.

4) *Future plans*
   - The District plans to construct and operate an additional two over/under bypass gates in the year 2007 and will continue to investigate ways of improving efficiency and decreasing cost while achieving standards.

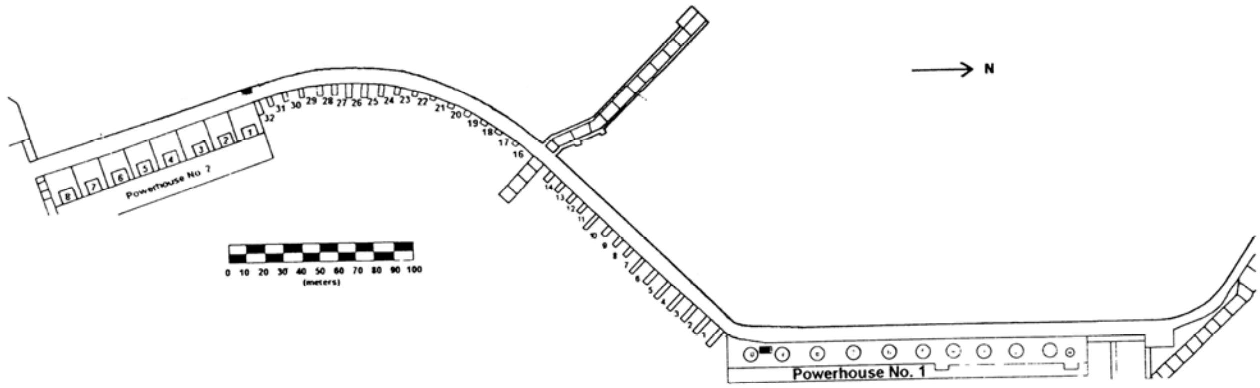
O) Conclusions and lessons learned (from all designs):

1) *Data gaps identified*
   - Biological performance of sub-yearling Chinook.
2) *Guiding principles/recipes for success*
   - Recognize each project is different and likely has characteristics which are unique concerning fish passage.
   - Develop and test hypotheses related to fish passage development through the use of field studies and modeling.
   - Engage multiple disciplines and plant operating personnel in design and testing deliberations and plans.
   - Recognize turbine passage is part of the equation in project survival.
3) *Pit falls, i.e. what not to do*
   - Assume what has worked on one project will work on another.
   - Assume that there is a single value of bypass flow or percent of spill that is necessary to achieve a project standard for every year
   - Neglect the inter-annual biological variability of each species.
4) *Absolute requirements*
   - Set survival goals then develop plans to work toward achieving those goals through design development and field testing.
5) *If you had it to do all over again, what would you do differently?*
   - Not get caught up in basin-wide initiatives, such as screening, but analyze the characteristics of the project that can be best utilized to advantage in achieving a high rate of survival.

P) Exhibits:

1) *Aerial photo*

2) *Current project layout with SFO*



Gates used for top spill are outlined above in section D.

3) *Forebay bathymetry*

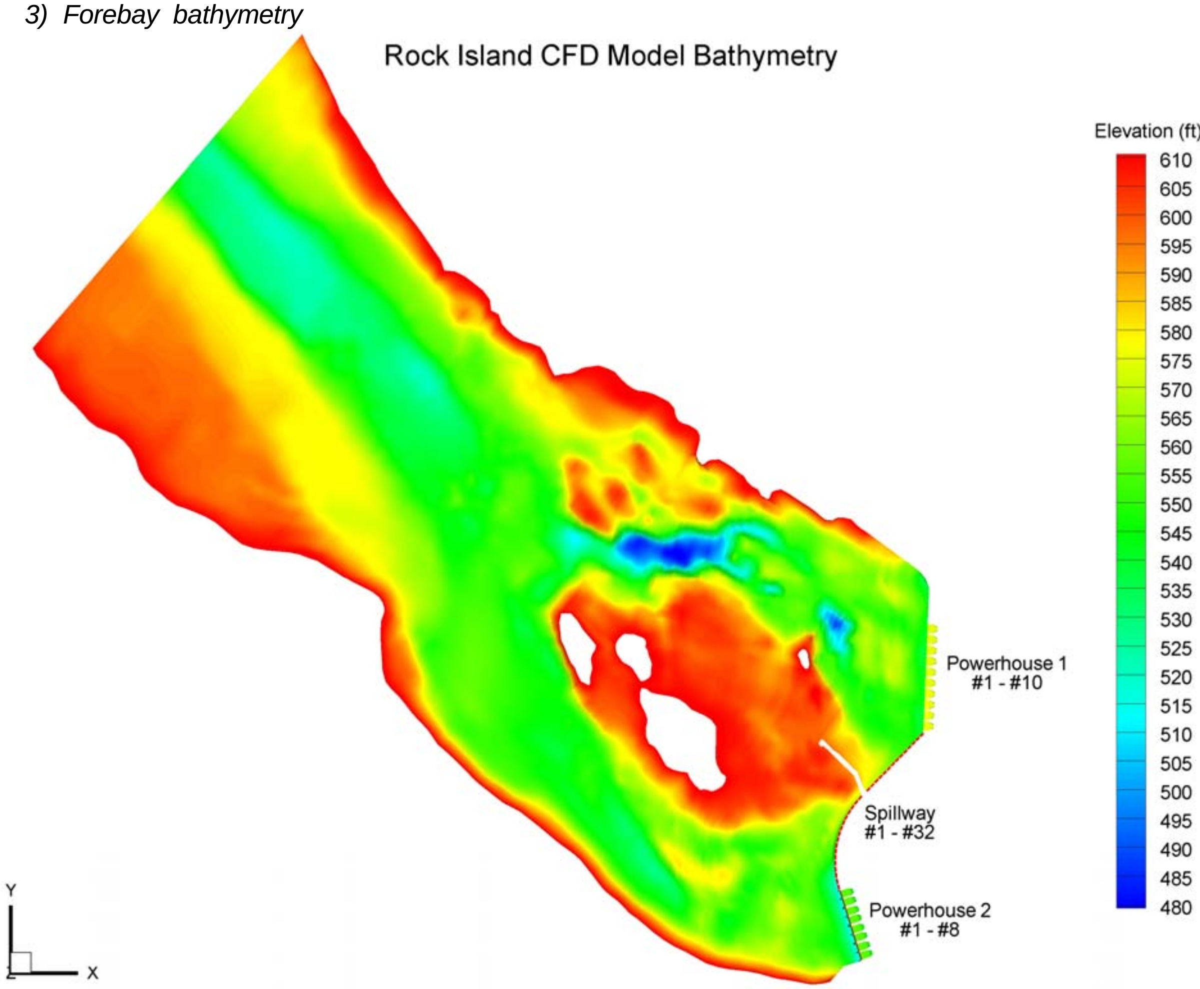
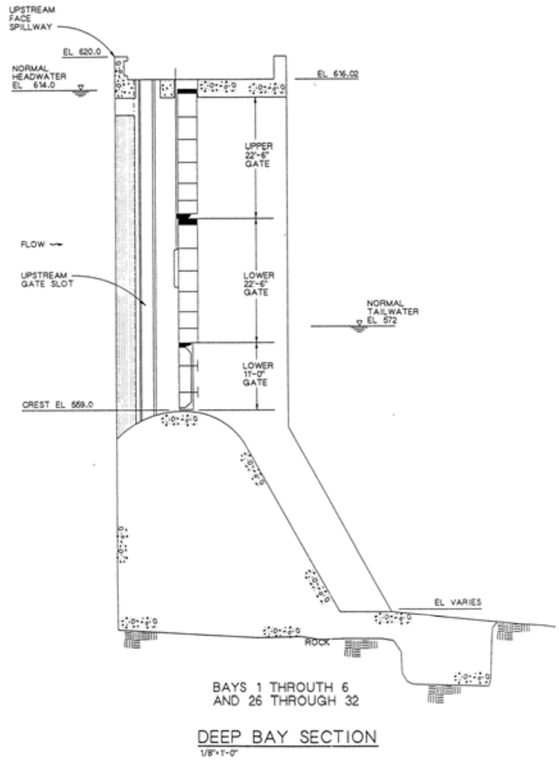
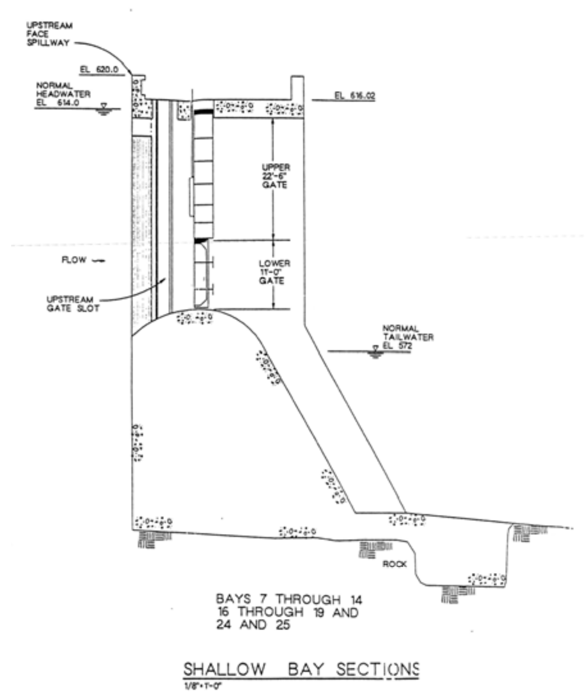


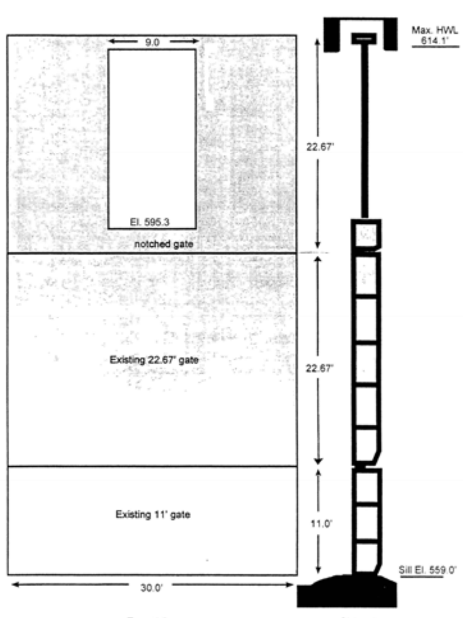
Figure General view of the CFD model bathymetry of Rock Island Dam Forebay

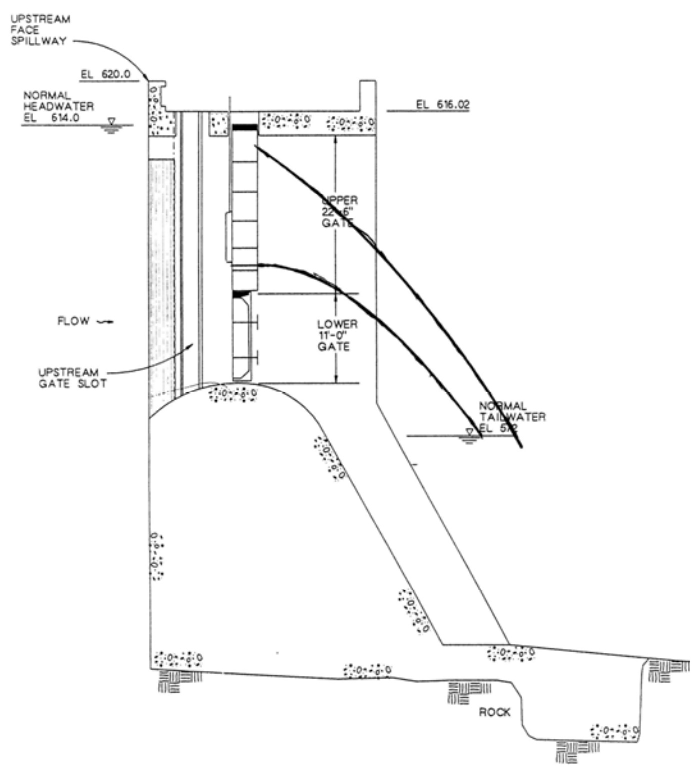
4) *Current plan and profile of the SFO structure*

- Typical configurations of notched and over/under gates are shown below.

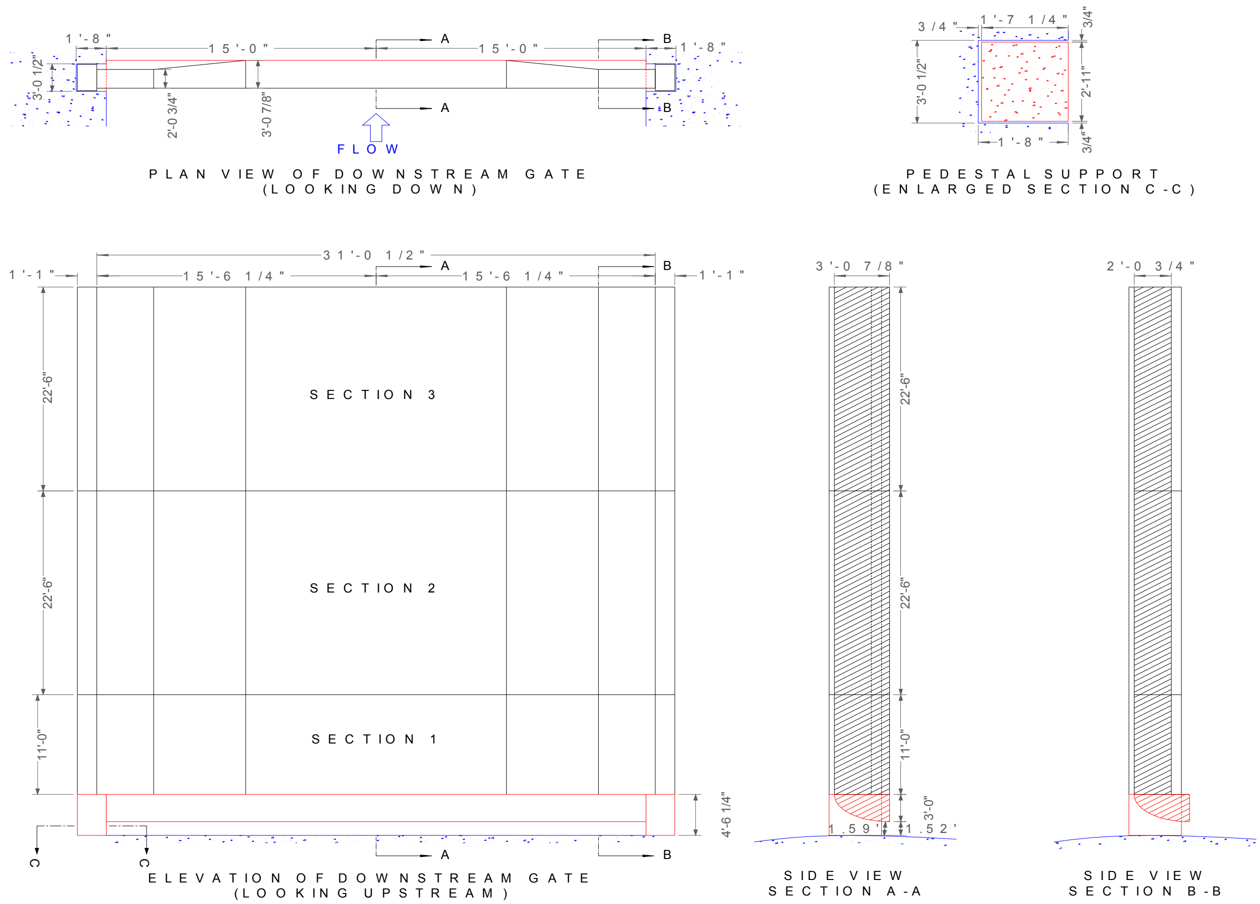








9 ft Notched Gate **9 ft Notched Gate Nappe**



5) *Forebay flow fields*

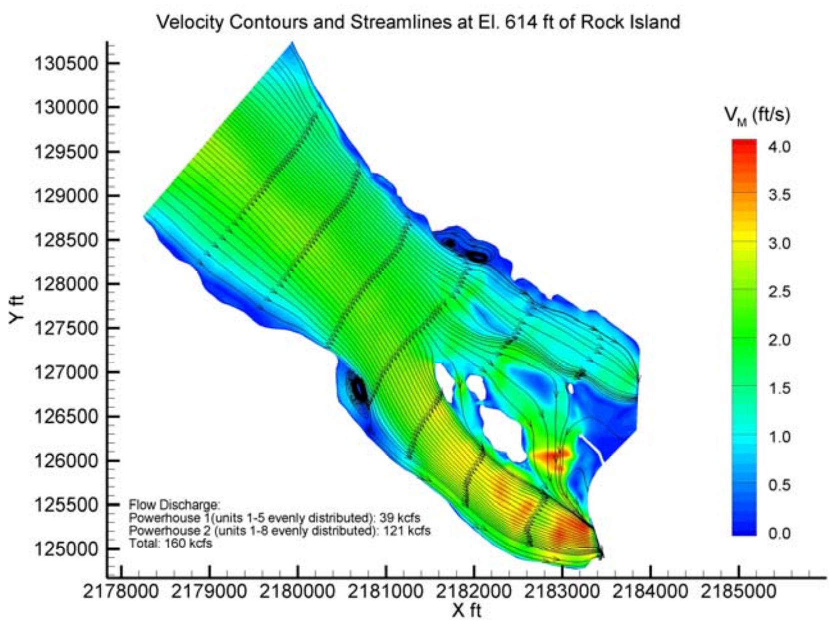


Figure Velocity contours and streamlines at elevation 614 ft of Rock Island Dam Forebay- no top spill

Project Description

Project: Wanapum Surface Bypass

Presenter: ***Curt Dotson (Grant PUD)***

Completed By: Duncan Hay

Email: duncanhay@shaw.ca

Phone: 604-936-5161

Date: October 6, 2006

A) Introduction:

1) *Why was SFO considered?*
   - To achieve survival of 95% of juvenile salmonids passing Wanapum Dam.
2) *What initial data kick-started the process?*
   - The high ratio of bypassed fish to flow rate at the trash and ice sluice adjacent to spillway bay 12.
   - Hydroacoustic, acoustic and balloon tag data from prototype topspills in spillway bay 12.
3) *What SFOs were investigated (model or prototype)?*
   - A prototype surface collector fashioned in an attempt to reproduce the fish bypass efficiency at Wells Dam was constructed and tested in front of the powerhouse in 1995, 1996 and 1997.
   - A slotted topspill bulkhead was modeled and prototype tested in spillway bay 12 in 1996 and in spillway bay 10 in 1997 at flows of 2,000 and 4,000 cfs.
   - A 40-ft wide 20-ft deep notched topspill bulkhead was modeled and prototyped tested in spillway bay 12 in 2002 and 2003 with a flow of nominally 11,000 cfs
   - A 32-ft wide 38-ft deep notched topspill bulkhead was modeled and prototype tested in spillway bay 12 in 2004 with a nominal flow of 20,000 cfs.
   - Hydraulic and CFD models were used in 2003 to 2006 to test concepts and develop a final design for a fish bypass adjacent to powerhouse in a skeleton bay originally set aside for future powerhouse units. It was referred to as the Future Unity Fish Bypass (FUFB).
   - A modification to the trash and ice sluice was designed and model tested in 2004 with subsequent field testing in 2004 for evaluating fish survival under exit conditions associated with the fish bypass.
   - Construction of the FUFB commenced in 2006 and is scheduled for completion and operation in 2007.

B) SFO: Prototype Surface Collector

1) *History of development and testing with the decision path.*
   - Development and testing of methods to enhance the passage and survival of listed species of salmonids commenced in 1984 with the testing of a net to divert smolts away from the powerhouse toward the spillway. The lack of success with the diversion net was replaced with studies and testing of wedge-wire diversion screens from 1990 to 1994 which were discontinued due to concerns about descaling, impingement and stress. The success of fish passage at Wells Dam drew some attention and led to testing to assess whether bypass slots of similar size and flow as those at Wells could be located above the powerhouse intakes.
2) *What modeling and prototype development was done?*
   - 1994 – Some model testing on a 1:16 scale model of a single powerhouse unit that had been used for diversion screen testing to test the alignment of a slot relative to the face of the powerhouse (Weber et al, 1994)
   - 1995 – A ‘surface flow attraction channel’ was constructed in front of powerhouse units 7, 8 and 9 with a vertical bypass slot centered on unit 8. The channel was 12-ft wide and extended 60 feet from above the water surface to several feet below the soffit of the turbine intake. The slot was designed to pass 280 to 1400 cfs at variable widths of 4-16 feet and opening heights of 15 to 50 feet. It was designed to test with velocities or 2.5 to 4.5 fps at the bypass opening. Fish bypass efficiency was very low and it appeared the channel shunted fish toward the lower numbered units (Ransom et al., 1996).

- 1996 – The channel was extended to cover the area above turbine units 4 through 9 and part of unit 10 and a slot was added above unit 6. Fish bypass efficiency remained low. (Normandeau et al., 1996)
- 1997 – The channel was extended to cover the entire face of the powerhouse, except one-half of unit 10. Fish bypass efficiency was about 1% (Kumagai et al., 1997.)

3) *Why was the SFO discarded as a design alternative?*
   - The surface attraction channel was not pursued because of poor fish bypass efficiency. It was hypothesized later than this may have been due to a deceleration in the surface flow approaching the bypass openings.

C) Prototype Slotted Bulkhead

1) *History of development and testing with the decision path.*
   - The 20- ft wide ice and trash sluiceway adjacent to spillway bay 12 historically bypassed about 10% of the smolts with a flow of about 2,000 cfs. The relatively high percentage of fish passage at this location led to the question as to whether this could be improved by passing the fish and flow through vertical slots rather than over a broad crested weir.
   - The concept was to install a bulkhead with vertical slotted openings against the spillway pier noses at spillway bay 12 and control the bypass flow by opening the tainter gate which was located immediately downstream of the bulkhead.
2) *What modeling and prototype development was done?*
   - 1995 – A 1:21.5 hydraulic model was constructed and tested at IIHR (Mannheim and Weber, 1997)
   - 1996 – A 67 ft wide by 78 ft tall bulkhead was installed at spillbay 12. The width of the spillbay was 50 ft. Four 6.25 ft wide by 20 ft deep slots were constructed in the bulkhead with two of the slots having doors that could close the flow through these slots. The bulkhead was designed for testing at 2,000 or 4,000 cfs. An evaluation by hydroacoustics indicated that about 11 percent of the fish passing the project during the spring used the slotted bulkhead although the percent of fish passing through the ice and trash sluiceway was reduced (Birmingham et al., 1997). Balloon tag tests estimated direct survival of 92.0 percent when discharging 2,000 cfs and 96.0 percent while discharging 4,000 cfs. The ice and trash sluiceway survival was estimated at 97.4 percent (Normandeau et al., 1996a)
   - 1997 – The slotted bulkhead was moved to spillbay 10 and operated at a bypass flow of 4,000 cfs. An average of 4.3 percent of fish passing the project used this route during the spring of 1997. The percent of fish passing via the ice and trash sluice increased over what was observed in 1996 (Birmingham et al., 1997)
3) *Why was the SFO discarded as a design alternative?*
   - Flow control using the tainter gate did not give satisfactory control or hydraulic conditions between the bulkhead and face of the tainter gate. It was also thought that larger flow releases may be required to achieve the percent of fish passage required for the project and this could not be readily achieved through the vertical slots.

D) Future Unit Fish Bypass (FUFB)

1) *History of development and testing with the decision path*.
   - A study team comprised of District staff, Agency personnel and consultants was formed in 2001.
   - The study team embarked on two initiatives; the construction and testing of an 11,000 cfs topspill fish bypass in spillbay 12 in 2002, and an assessment of alternative fish bypass concepts with input from field data, model studies and premises of fish behavior.
   - A report on the fish passage alternatives study was finalized in 2003 (Jacobs et al., 2003). The report identified thirteen basic alternatives and ranked these into three tiers using 14 to 16 un-weighted evaluation criteria. Included in top tier were top spill in the area of the future units and advanced turbine design. Work on the advanced turbine design proceeded independently from the fish bypass design team work.

- The alternative selected for design development and evaluation at Wanapum Dam was a concept that routed bypass flow through a free-surface outlet at one of the future unit monoliths adjacent to the powerhouse.
- A design team plan for the advancement of the preferred alternative was developed and implemented in 2003. The study plan included the design objective; strategies, detailed tasks, decision tree, and schedule.
- Strategies included:
  - Assessing survival and behavior associated with existing spillway and turbine passage routes
  - Undertaking prototype evaluations to guide design development
  - Designing the non-turbine passage routes such that it is possible, if necessary, to incrementally add measures to enhance fish passage through fish guidance or diversion devices in the forebay.
  - Undertaking radio, acoustic tag, and/or PIT-tag studies to support prototype evaluations and to determine route-specific survival and combined passage route survival to assess achievement of the fish passage objective, and
  - Assess, design and implement other Tier 1 or Tier 2 non-turbine passage alternatives identified in the 2003 Fish Passage Alternatives Study until the fish passage objective is met.
- Tasks included:
  - Developing design guidelines
  - Developing as assessing design concepts for a range of bypass flow rates
  - Assessing fish behavior at bypass entrances
  - Assessing fish survival at the bypass exit
  - Hydraulic, CFD and Numerical Fish Surrogate Modeling
  - Prototype testing and evaluation
  - Preliminary design and evaluation
  - Final design and implementation
  - Field testing and evaluation.
- Sept 2004–Jan 2005: Final Hydraulic Design and Permitting
- 2004 – 2006: Final structural, mechanical and electrical design
- Jan–July 2005: Project bidding and contract award
- July 2005: Commenced construction
- March: 2007Construction Completed
- March/April 2007: Testing/Operation

2) *What modeling and prototype development was done?*
   - 1996 – A 1:50 scale model of the forebay was constructed and used through to 2005 to assess various fish bypass alternatives and then assist in developing the final hydraulic design of the FUFB as it related to the hydraulics of approach flows, zone of influence, and flow competition with the powerhouse (Haug et al., 2003, Lyons et al., 2005).
   - 1999 – A 1:52 scale model of the tailrace was constructed and used through to 2005 to examine hydraulic conditions in the tailrace with respect to fish egress, TDG and riverbed erosion (Haug et al., 2003, Lyons et al., 2005).
   - 2001 – Separate CFD models of the forebay and tailrace were developed and subsequently used to assess hydraulic conditions and parameters associated with various fish bypass options. The forebay model was used to produce outputs for specific project flow distributions for use with the Numerical Surrogate Fish Model (Li and Weber, 2006, Li and Weber 2006a, Li and Weber 2006b, Weber and Li, 2006c).
   - 2002 – A topspill bulkhead was constructed in spillbay 12 to pass nominally 11,000 cfs. The bypass opening was 40 ft wide and 20 ft deep at normal pool elevation. Fish bypass efficiencies and survival were assessed by radio and balloon tags (Robichaud et al., 2003, Normandeau and Skalski, 2003).
   - 2003 – The topspill configuration used in 2002 was left in place and performance again monitored through the use of radio tagged fish.
   - 2003 – Two hydraulic designs were prepared and carried forward for assessment for a bypass flow of 20,000 cfs adjacent to the powerhouse. The major difference between the two was the area of the bypass opening. Concept 10 had a velocity at the entrance piers of about 13 fps whereas for

Concept 11 the velocity at the same location was about 4 fps. Exit velocities at a flat angle to the tailrace where 65-70 fps for both concepts.
- 2003 – In December the construction of a 1:24 scale facility was initiated to model and evaluate Concepts 10 and 11. The model was used in preliminary assessments and then to assist in the final hydraulic design related to bypass flow capacities, water levels, crest pressures, air demand, entrance conditions, exit jet characteristics, and regulating and emergency closure gates. This hydraulic model was used in conjunction with a CFD model that used the FLUENT code to define velocity and pressure distributions as well as cavitation numbers.
- 2004 – The topspill configuration in spillbay 12 was modified to pass a nominal flow of 20,000 cfs being the design flow for the FUFB in order to undertake specific prototype tests related to the design of the bypass.
  - The tests were undertaken to develop fish passage collection efficiency data to apply to the FUFB design to estimate the fish passage efficiency expected at the FUFB and assess whether fish rejected a bypass opening where all the acceleration up to trapping velocity occurred within the forebay. The data also provided a comparison with 2002 and 2003 data when the bypass flow was less.
  - Tests were conducted with only the topspill and powerhouse operating to avoid confounding the fish passage efficiency and fish entrance behavior tests with flow through the spillway.
  - Tests were conducted with powerhouse operation only to obtain a measure of the density of smolts in the vicinity of the future FUFB to facilitate an estimate of the fish bypass efficiency of the FUFB.
  - Acoustic tagged smolts were used in the study.
  - Testing Criteria
    - > 80% FCE: no fish rejection of bypass, move ahead concept 10
    - 60%-80% FCE; fish may be rejecting bypass, conduct further evaluations
    - <60% FCE; fish are rejecting bypass, move ahead concept 11
  - The results of the tests were as follows (Robichaud et al., 2005. Robichaud et al., 2005a):
    - No apparent rejection of the top spill opening based on hydraulic conditions;
    - Rejection at 50 feet was less than 1%;
    - Fish Passage Efficiency (FPE) was 25.6%;
    - Fish Collection Efficiency (FCE) at 300 feet was 86%;
    - Major approach path was along face of future units.
- 2004 – The ice and trash sluiceway was modified and used to prototype test the survival of smolts under exit conditions incorporated in the design of the FUFB. The hydraulic design of the sluiceway modifications was model tested at a scale of 1:12 (Reid and Hughes, 2004). The design converted the sluiceway from a free fall overflow to a contained spillway chute that narrowed from 20 ft wide at the entrance to 8 ft wide at the exit giving an exit flow of about 220 cfs/ft and exit velocities of 65 fps. The invert elevation of the exit was set to correspond to design conditions for the FUFB.
  - The results of the tests were as follows (Normandeau and Battelle, 2005):
    - Nominally 100 percent survival
    - Injury rate 2 percent
    - The only injuries were minor abrasions
    - No “typical” spillway passage types of injuries observed
    - No pressure spikes or anomalies observed
- 2004 – Concept 10 was selected for final design based upon the results of the prototype evaluations. The final hydraulic design of the FUFB was completed (Hay, 2005) and work on the final structural, mechanical and electrical design was advanced.

E) Present status of facility:

1) Project layout/bypass system configuration:
- Located adjacent to powerhouse unit 10
- Designed to pass 20,000 cfs at normal pool with all gates fully open.
- Designed to pass with regulated topspill flows of 2,000, 5,000, 10,000 and 15,000 cfs.
- Bypass opening is 18.5 feet wide by 84.8 feet deep giving an entrance velocity at the dam face of 12.75 fps for full bypass flow.

- Discharge is spread to a 90-ft width, elevated to minimize TDG and river bed scour and adjacent to turbine flows to facility egress of the smolts in the mid-channel area.

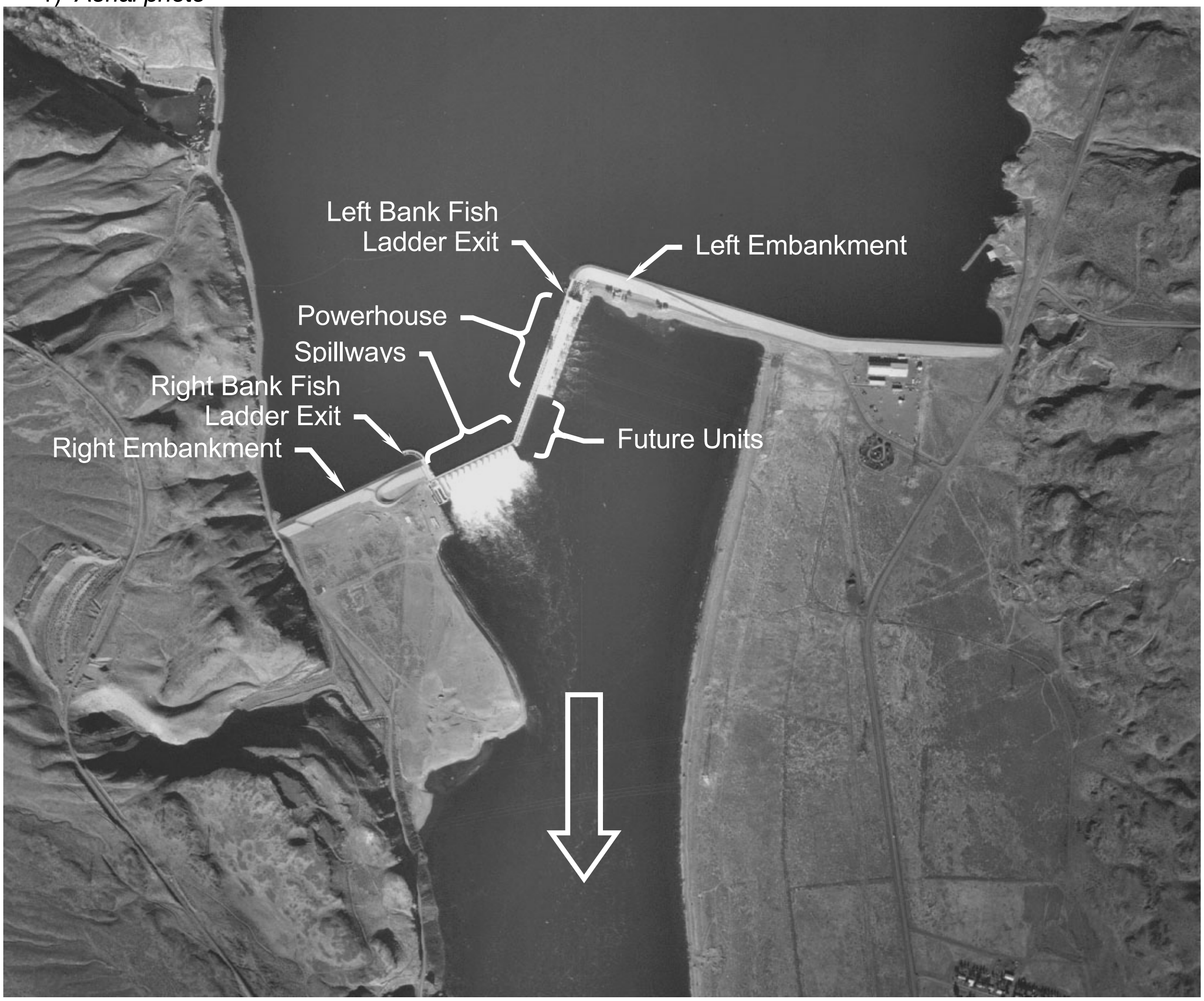
2) *Cost (Design, Construction, Evaluation)*
   - $ 5 million in design work
   - $ 32 million to construct
   - $ 4 million in biological evaluation (pre- and post- construction)
3) *Biological performance*
   - Initial biological evaluations will be undertaken in 2007
4) *Future plans*
   - Complete construction in 2007 and commence operation and evaluations.

F) Conclusions and lessons learned:

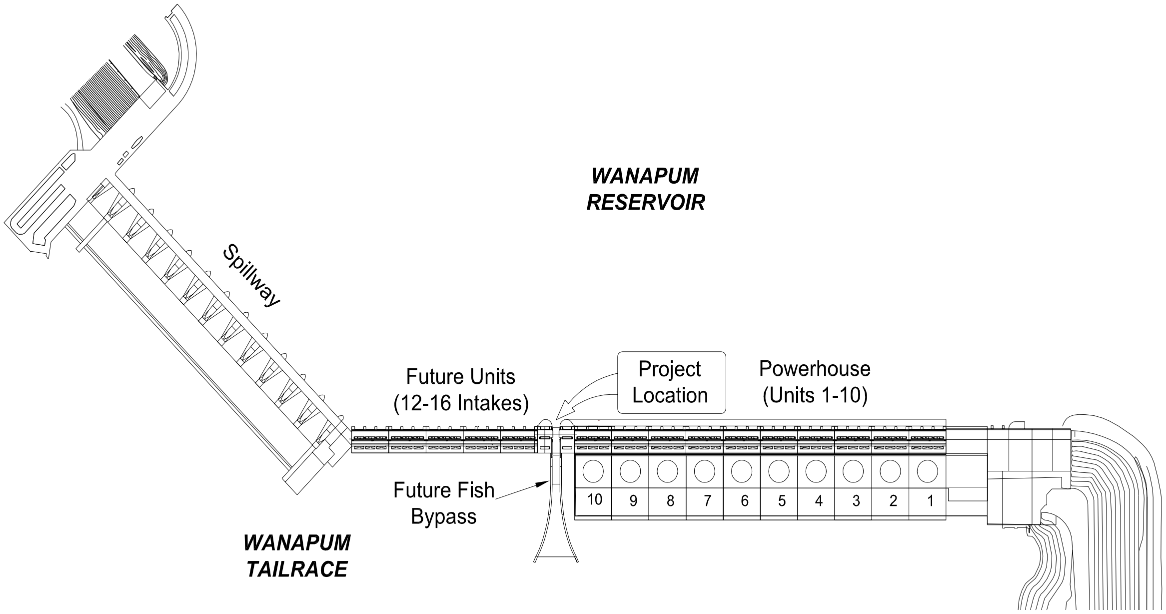
1) *Data gaps identified*
   - The bypass flow required to achieve a given level of fish collection efficiency remains as one of the most difficult parameters to quantify during the design process.
   - There are numerous hypotheses with respect to the behavior and survival of fish in given hydrodynamic conditions but very few definitive studies that have been undertaken at an appropriate physical scale outside of the confines of restricted laboratory space to test these hypotheses.
2) *Guiding principles/recipes for success*
   - Clearly identify the project objective, goals, and design guidelines.
   - Layout a clear path forward that defines the tasks and assessments required to develop the design
   - Undertake prototype field tests with fish to assess the potential fish passage efficiency, behavioral characteristics and survival. Test design assumptions (hypotheses) that are integral to the success of the project.
   - Work close with the regulatory agencies in the development of concepts through to final design.
3) *Pit falls, i.e. what not to do*
   - Blindly apply what has been successful on other projects
   - Implement a design based upon an untested hypothesis.
4) *Absolute requirements*
   - Consider the project unique.
5) *If you had it to do all over again, what would you do differently?*
   - Not construct the surface collection channel tested in 1995 to 1997 which was based upon attempting to reproduce the fish bypass success at Wells Dam with what was thought to be a similar configuration.

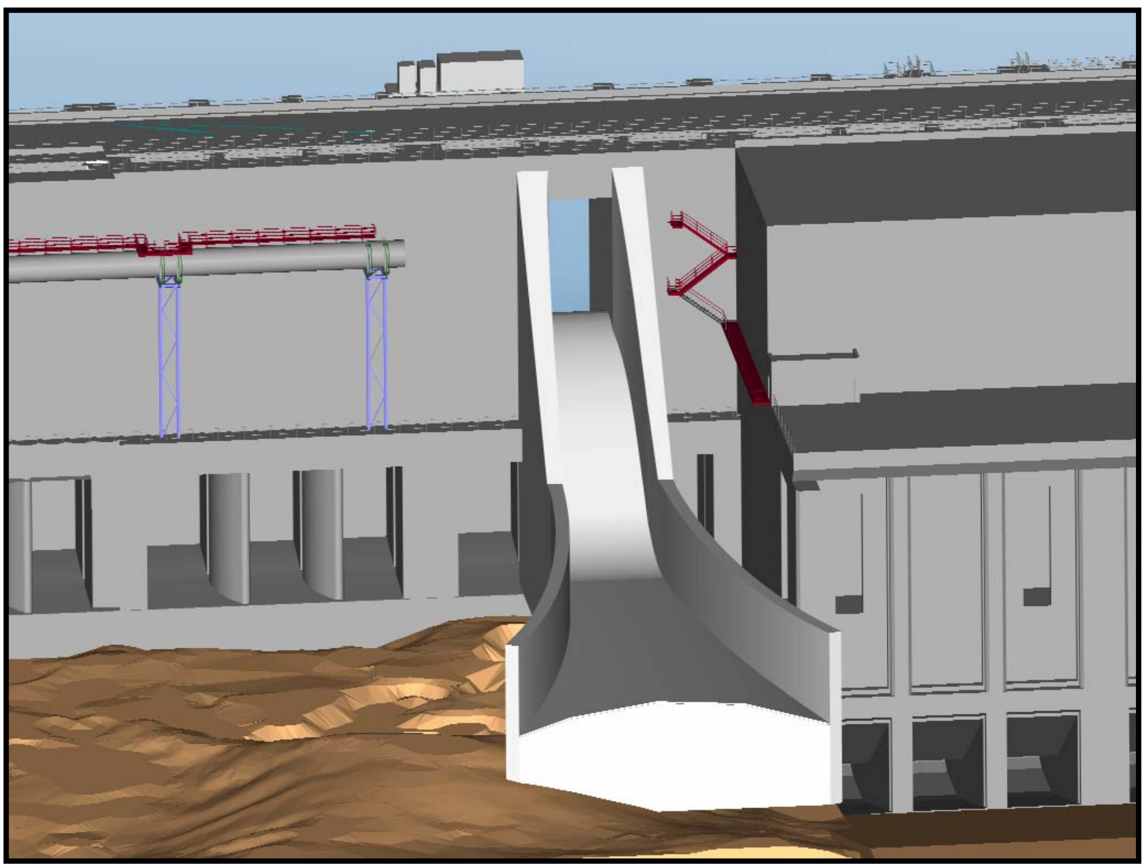
G) Exhibits:

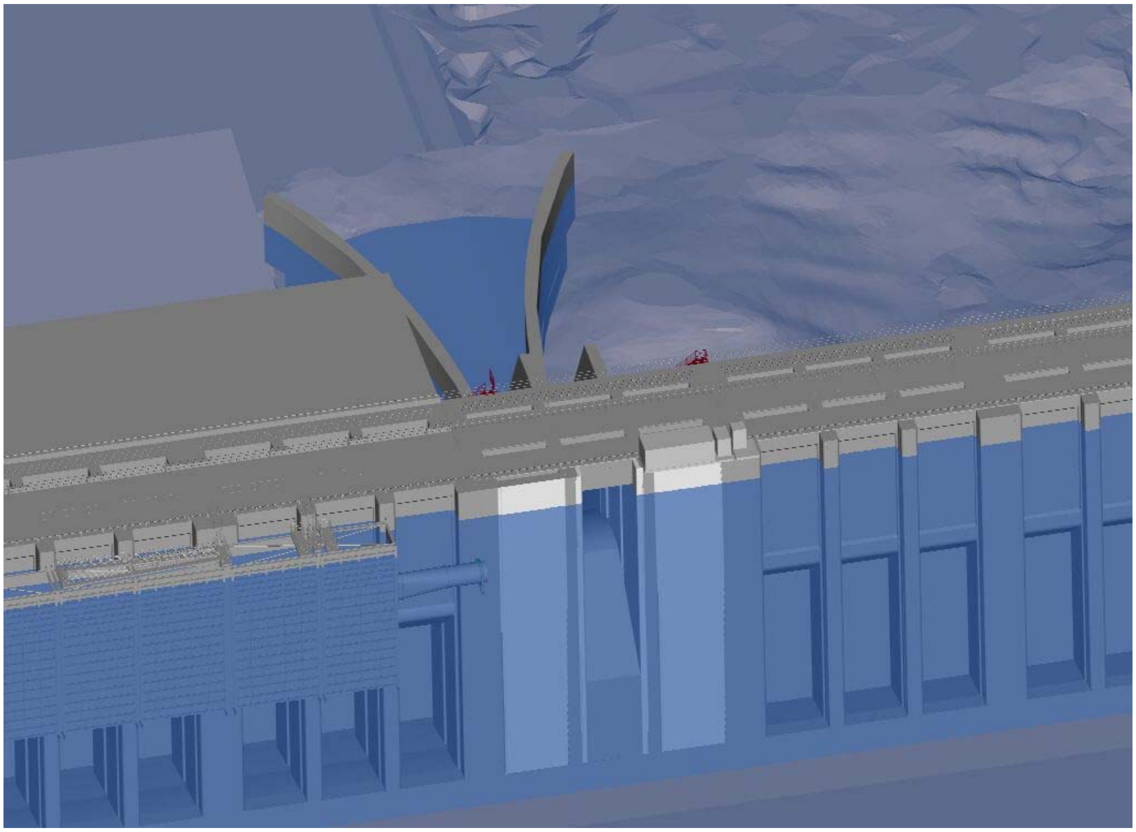
1) *Aerial photo*



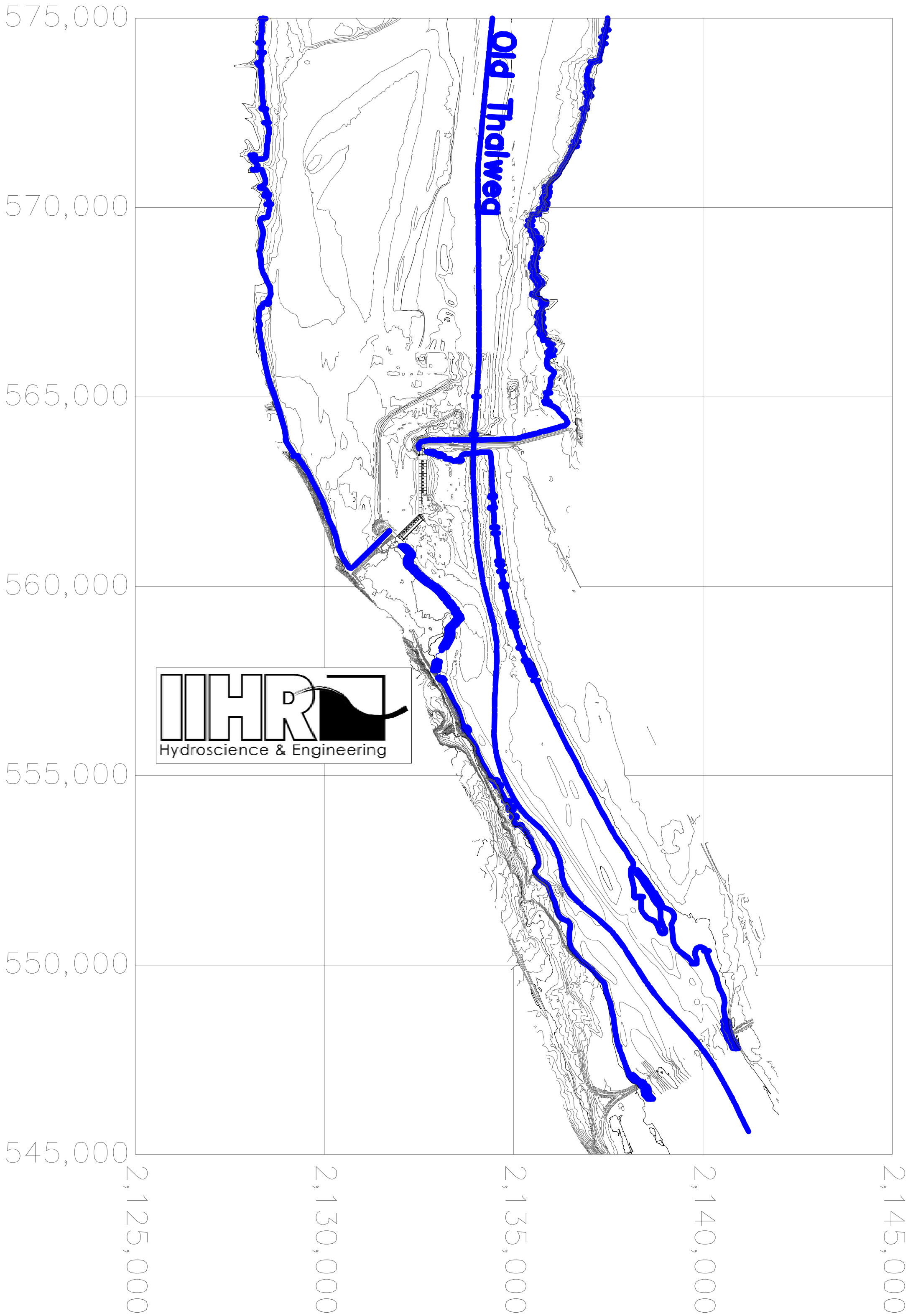
2) *Current project layout with SFO*





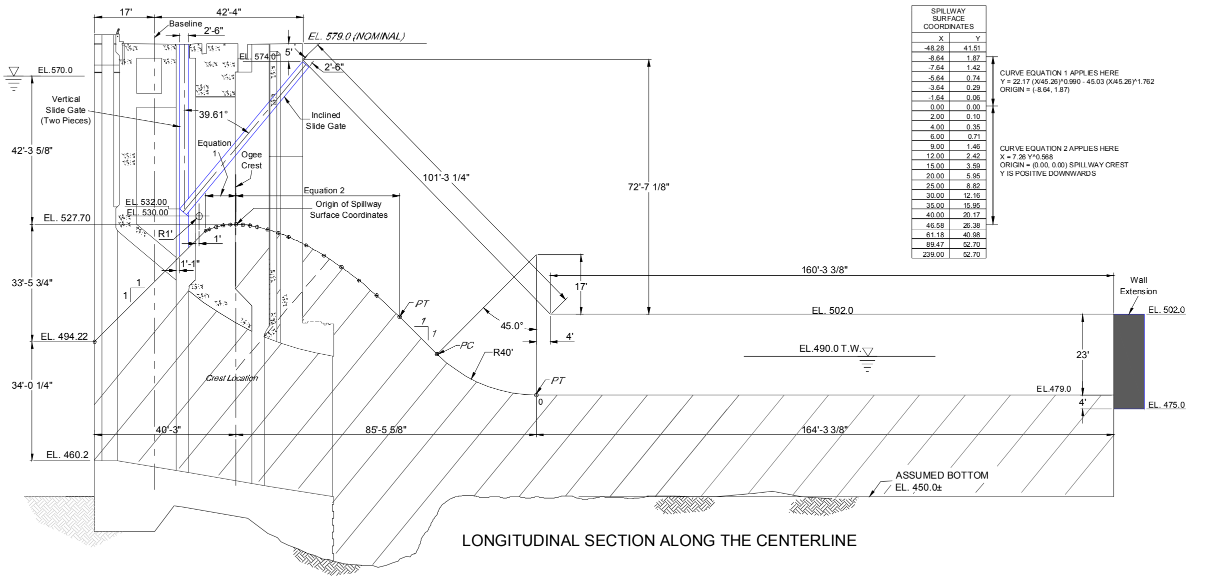


3) Forebay and tailrace bathymetry



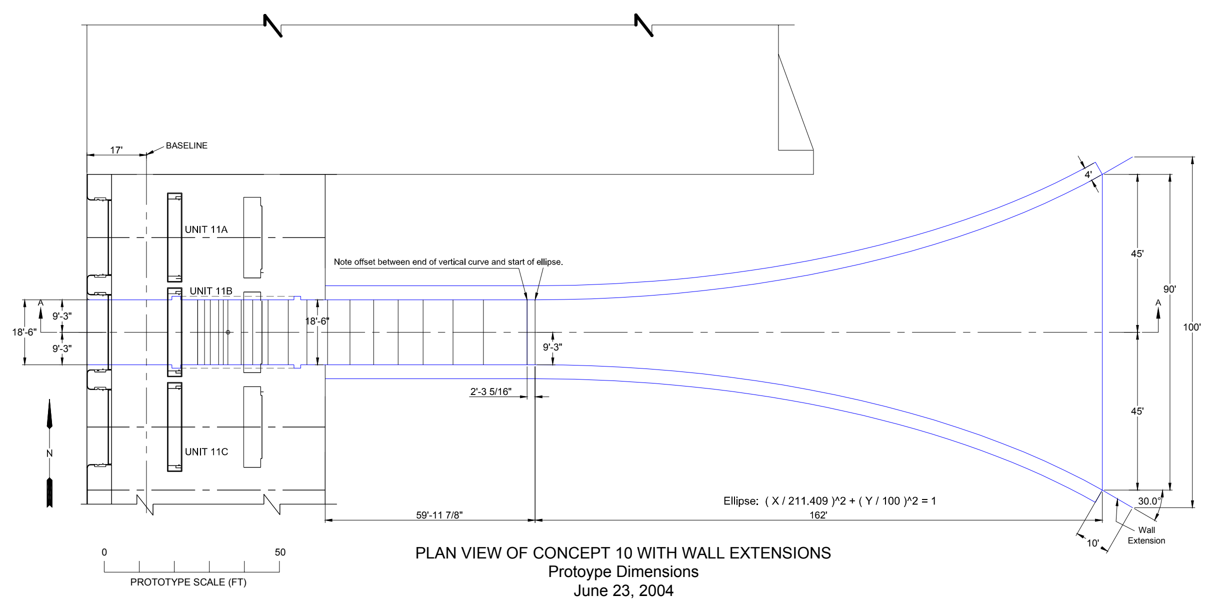
Wanapum Dam Forebay and Tailrace Contours showing thalweg and normal water levels in blue

4) *Current plan and profile of the SFO structure*



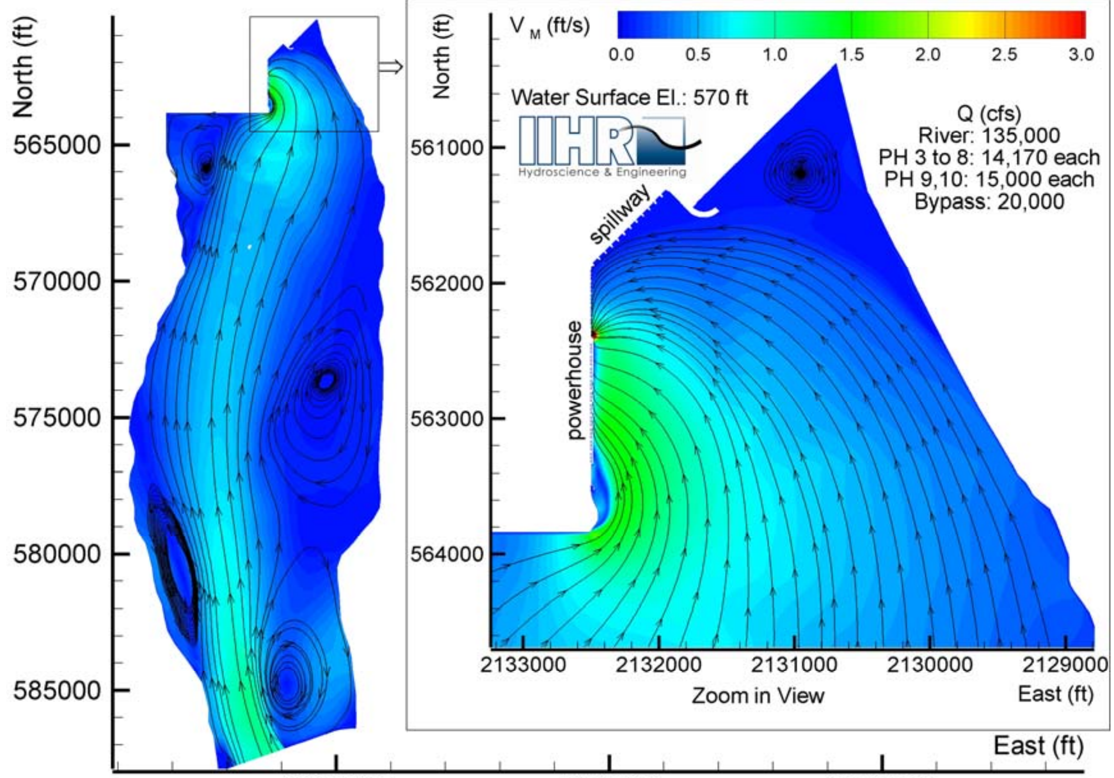
SPILLWAY SURFACE COORDINATES	
X	Y
-48.28	41.51
-8.64	1.87
-7.64	1.42
-5.64	0.74
-3.64	0.29
-1.64	0.06
0.00	0.00
2.00	0.10
4.00	0.35
6.00	0.71
9.00	1.46
12.00	2.42
15.00	3.59
20.00	5.95
25.00	8.82
30.00	12.16
35.00	15.95
40.00	20.17
46.58	26.38
61.18	40.98
89.47	52.70
239.00	52.70

LONGITUDINAL SECTION ALONG THE CENTERLINE

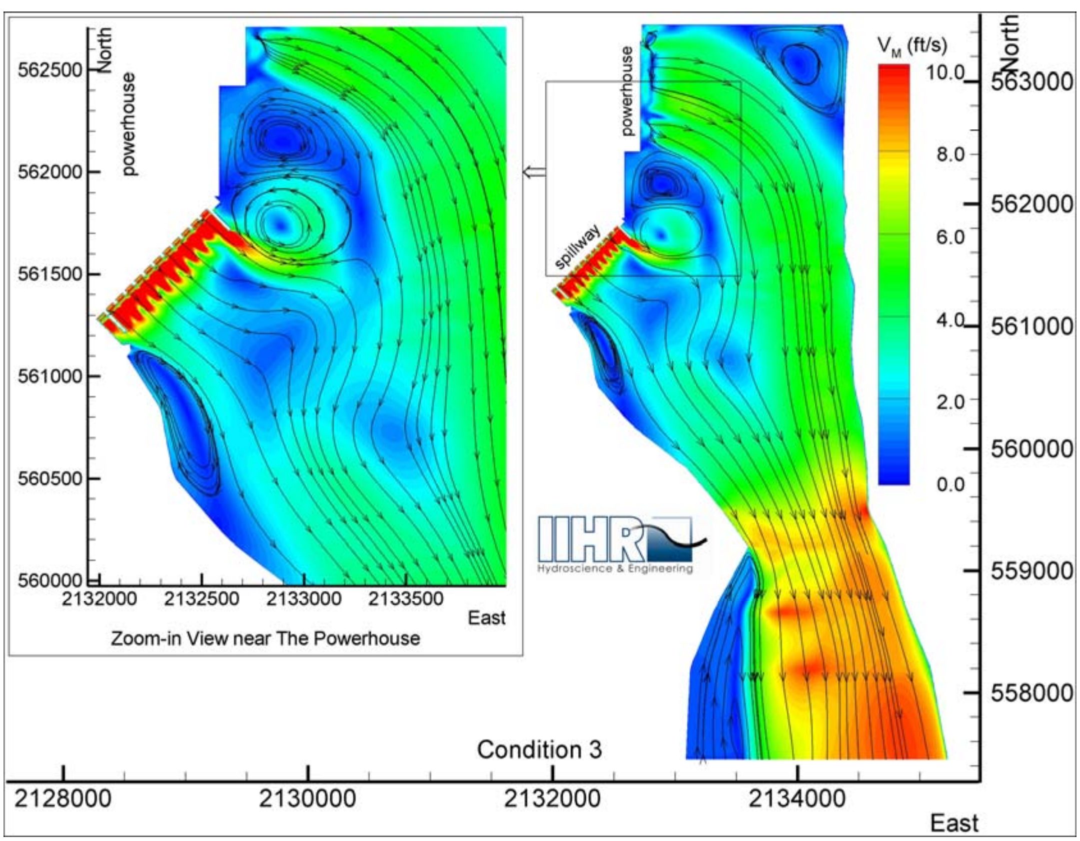


PLAN VIEW OF CONCEPT 10 WITH WALL EXTENSIONS
Protoype Dimensions
June 23, 2004

5) *Forebay & tailrace flow fields*



Wanapum Dam Forebay Velocity Contours and Streamlines



Wanapum Dam Tailrace Velocity Contours and Streamlines

ENSR | AECOM

Project Description

Project: Priest Rapids

Presenter:

Completed By:

Email:

Phone:

Date:

A) Introduction:

1) *Why was SFO considered?*
   - To achieve survival of 95% of juvenile salmonids passing Priest Rapids Dam.
2) *What initial data kick-started the process?*
   - January 2003 Fish Passage Alternatives Report
   - Wanapum gate 12 Top Spill Bulkhead 3-D Testing Results
   - More design and modeling work at IIHR
3) *What SFOs were investigated (model or prototype)?*
   - Spill bulkheads

B) SFO: Spill Bulkheads

1) *History of development and testing with the decision path.*
   - The District started taking a serious look at down stream migrants in the early 80's.
   - Installed and tested several downstream passage prototypes the results of which have pointed toward the need for a new top spill device at Priest Rapids Dam.
   - Currently spill 61% of total flow at Priest Rapids Dam during the spring fish passage season.
   - Priest Rapids has a high survival rate through the spillway, 95%. Need to balance that high survival rate with efficient use of water.
   - Goal is to maintain 95% survival rate or increase it through the dam by using the new top spill prototype.
2) *What modeling and prototype development was done?*
3) *Why was the SFO discarded as a design alternative?*

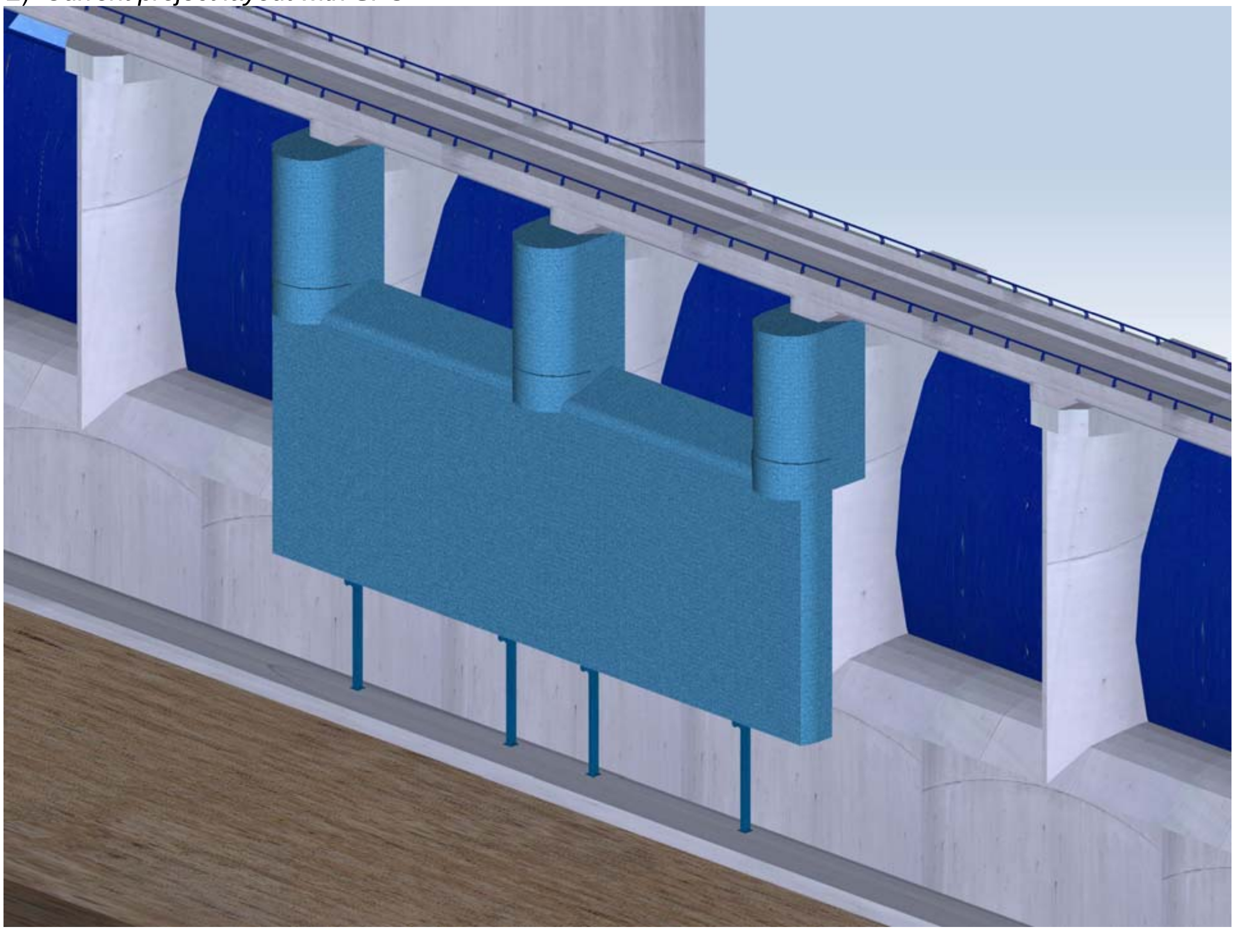
C) Present status of facility:
Under consideration.

D) Conclusions and lessons learned:
N/A

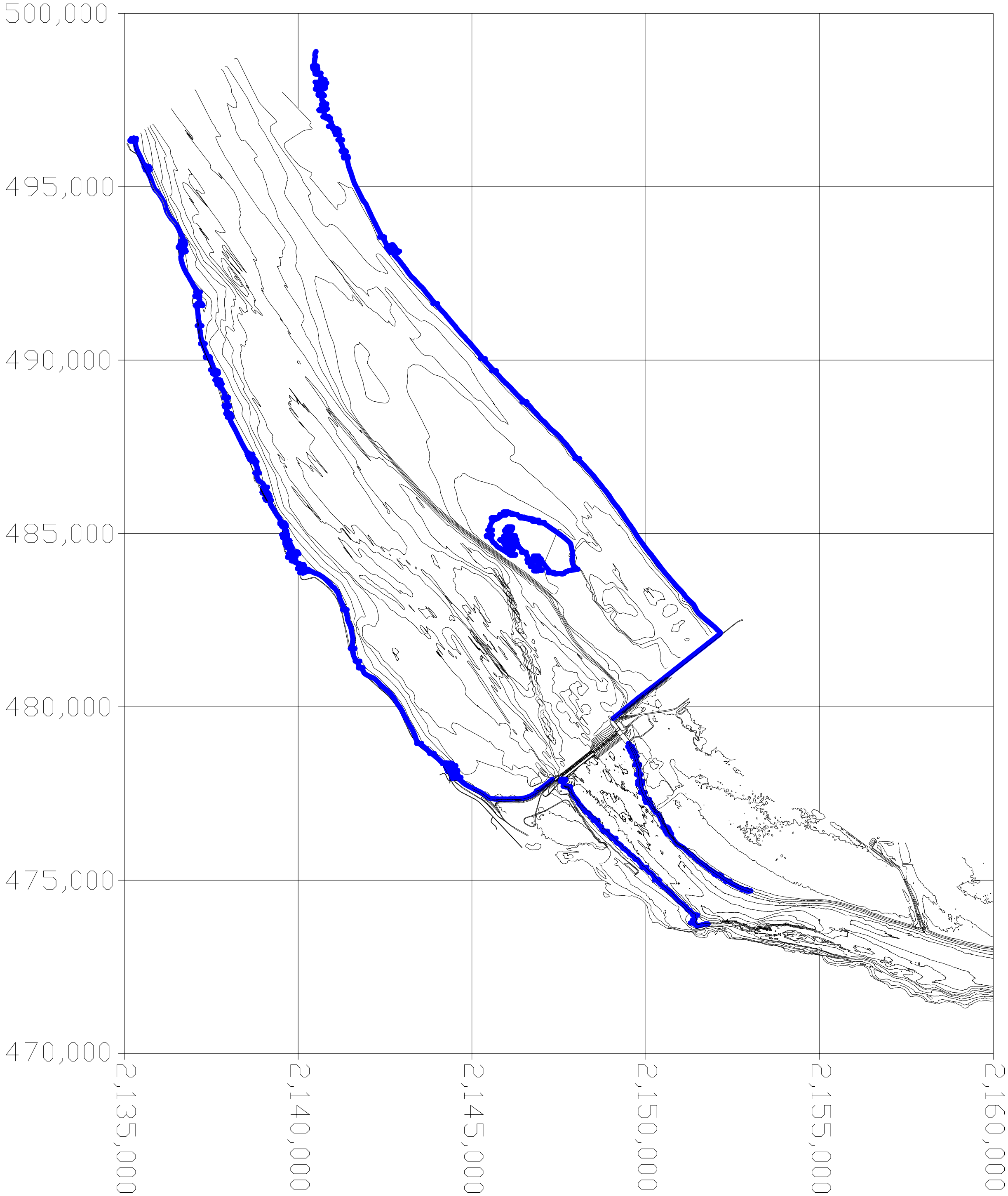
E) Exhibits:

1) Aerial photo

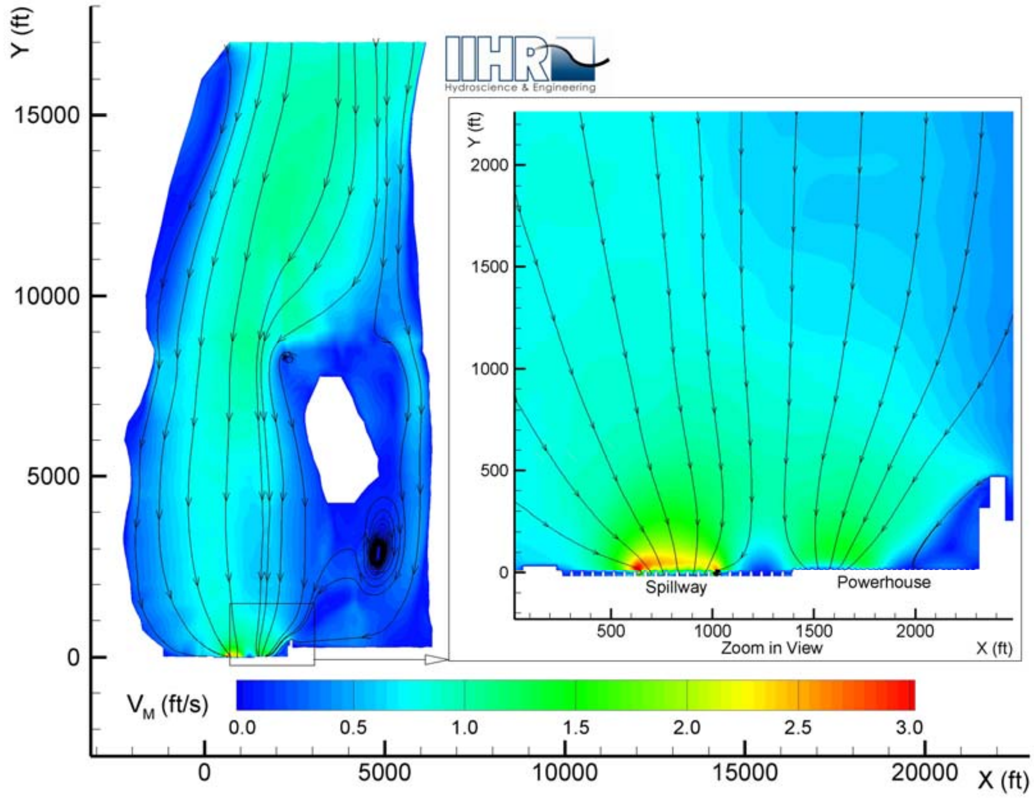
2) *Current project layout with SFO*



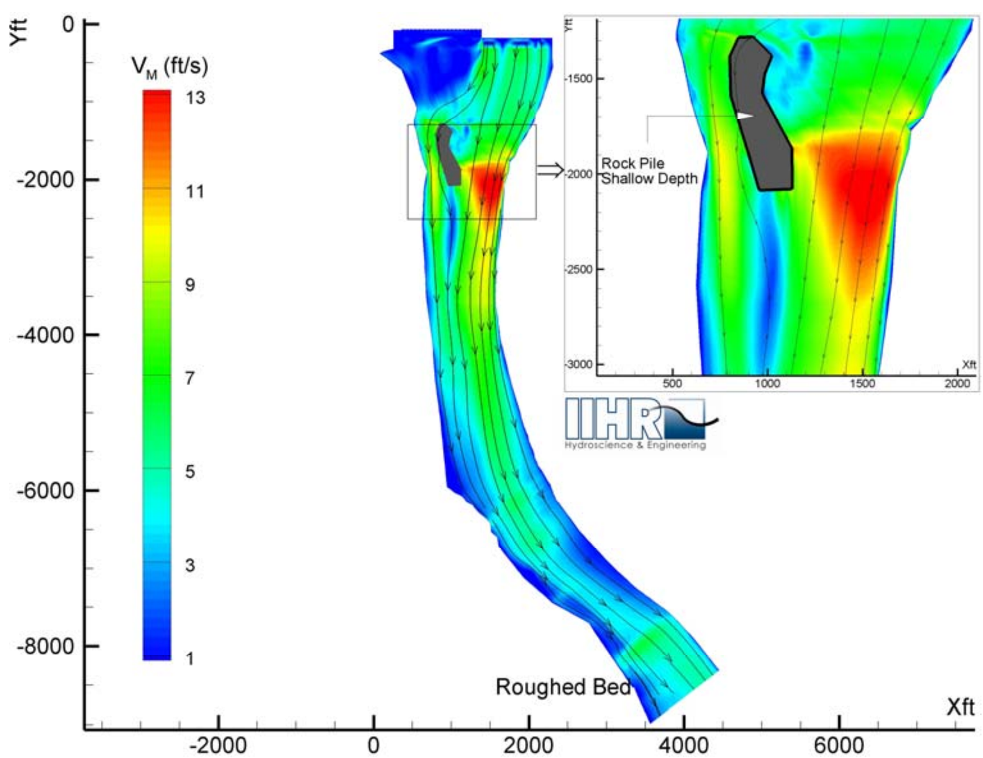
3) Priest Forebay and Tailrace Contours with Normal Water Levels in Blue



4) Priest Rapids Dam Forebay and Tailrace Velocity Contours and Streamlines



Forebay



Tailrace

ENSR | AECOM

Project Description

Project: Lower Granite Surface Bypass

Presenter: ***Lynn Reese***

Completed By: **Lynn Reese / Tim Wik**

Email: **lynn.a.reese@usace.army.mil**

tim.o.wik@usace.army.mil

Phone: **509-527-7531 (Reese)**

509-527-7206 (Wik)

Date: **October 30, 2006** (modified 1/4/07 GEJ)

A) Introduction:

1) *Why was SFO considered?*
   - SFO was one of the technologies identified within the Corps' Lower Snake River Feasibility Study (under Major System Improvements) that might be used to improve juvenile fish passage through the hydropower corridor. Evaluating the effectiveness and feasibility of SFO technology was one of the goals of this study.
   - Primary goal for SFO was to increase juvenile fish passage (and ultimately higher survival) through non-turbine routes by:
     - Lowering stress and injury
     - Reducing delay
   - SFO on spillway routes might also allow for reduced voluntary spill.
     - Improve water quality by reducing total dissolved gas (TDG) levels
     - Increase power revenues.
2) *What initial data kick-started the process?*
   - Examined the successful SFO at Wells Dam on the mid-Columbia.
   - Conducted preliminary work at Ice Harbor in 1995 (prior to permanent closure of the ice-trash sluiceway [i.e. sluice and surface spill tests] plus completed preliminary forebay guidance curtain physical model work) in order to gain insights for SFO work to be done at Lower Granite. The main finding from the IHR field testing relevant to Lower Granite was that a surface skimming configuration was noticeably more effective than gated spill flow.
   - Collected Lower Granite baseline radio telemetry and hydroacoustic data (mobile and fixed-location techniques) to get forebay approach patterns, forebay special distribution, and dam passage.
   - Collected Lower Granite forebay ADCP data.
3) *What SFOs were investigated (model or prototype)?*
   - Surface Bypass and Collection (SBC), a partial powerhouse prototype
     - Original structure with changes / additions over time (entrance gate modifications, Simulated Wells Intake [SWI] addition, Behavioral Guidance Structure [BGS] addition, operational changes).
   - Removable Spillway Weir (RSW) Prototype
     - With and Without BGS addition (Original and Modified BGS Versions)

Complete the following for each SFO identified in A.3. that was ultimately discarded (*<u>Note</u>: See B) 3) below for discussion as to what "discarded" means in this instance).*

B) **SFO Alternative 1 - SBC**

1) *What modeling and prototype development was done? Present in timeline format.*
   - 1994-95: Concept Development / SBC Design
   - 1996-97: SBC (Proof of Concept Tests)
   - 1998-99: SBC (SWI / BGS Additions)
   - 2000: SBC /SWI /BGS (Modified / High Flow Entrance)
2) *History of development and testing with the decision path.*
   - Hydraulic evaluations included:

  - Field measurements (ADCP data for general flow approach information and ADV data for specific entrance flow rate and turbulence information).
  - Numerical models (CFD for detailed hydraulic analysis related to both new designs and of constructed features).
  - Physical models (six physical models to evaluate different design components and project operations).
- Biological evaluations included:
  - Radio Tracking
  - Hydroacoustics
  - Balloon Tags Direct Survival / Injury
- Numerical Fish Surrogate (NFS) work to preliminarily evaluate fish behavior and hydraulics overlay for different configurations and project operations.
- Design considerations:
  - Located entrances in areas where fish approach project.
  - Configured initial system with flow rates and gate configurations similar to Wells Dam.
  - Designed partial powerhouse SBC and related structures for limited life (instead of full powerhouse systems with extended life) for cost saving reasons. Data obtained from testing would be used to obtain performance, design, and cost information with possible applications towards final permanent full project designs.
  - Collected data at Lower Granite with the added potential of possibly being able to transfer technology to other locations.
    - Overlay Fish Behavior / Hydraulics and Secondary Data.
  - Gained information that would have applications for both in-river and transport management strategies.
  - Considered high river flow / flood situations in the design of prototypes.
  - Completed preliminary model work and related evaluations pertaining to potential future large scale dewatering as part of SBC structure
  - Used lessons learned during early tests to make improvements in configuration and project operation for later tests (i.e. change to higher discharge overflow entrances, recommendation for gradual shaping for future entrances, addition of SWI to original SBC structure to influence vertical fish movements, addition of BGS to influence horizontal fish movements, evaluation of turbine operations to check impact on performance)
- Performance
  - The 1996 studies demonstrated proof-of-concept for the SBC surface flow bypass. The hydroacoustic estimate of SBC efficiency, relative to Turbine Units 4-6, was 43% (± 2%). For the project as a whole in 1996, the SBC passed about 10% (± 2.4%) of all radio-tagged Chinook salmon and steelhead (Johnson et al. 2000). Based on mobile tracking, radio-tagged fish appeared to follow the bulk flow in the forebay as they approached the dam (Adams et al. 1998b). Hydroacoustic data from mobile surveys in the forebay and fixed-location sites at the SBC showed that the vertical distribution was skewed toward the upper water column with roughly 80% of the fish within 15 m of the water surface (Johnson et al. 2000).
  - In a given study-year, new SBC configurations were designed and statistical comparisons of SBC passage efficiency performed with the intention of determining a best entrance condition. Based on the collective results from the 1996-2000 SBC research, the best tested entrance configuration was the Single Chute, which concentrated all of the SBC flow at a single outlet (one entrance 5 m wide and 8.5 m deep).
  - The 1996-2000 SBC research established the validity of the surface flow bypass concept for Lower Granite Dam. The radio telemetry and hydroacoustic data showed that generally over 50% of total fish passage into the section of the dam with the SBC was through the SBC, compared to about 10% of the water at that section of the dam (Turbine Units 4-5). By inference, the surface flow bypass concept is likely to be valid at the other dams in the lower Snake River (Little Goose, Lower Monumental, and Ice Harbor) because they are similar to Lower Granite Dam in terms of powerhouse size (6 turbine units), spillway size (8 spill bays), head (~30 m), orientation (perpendicular to river flow), discharge (run-of-river), and species

composition (predominately juvenile steelhead and subyearling and yearling Chinook salmon).

- Biological performance of the SBC for the Single Chute in 2000, the best configuration tested, was as follows: Data are from Anglea et al. 2001 (p.4.2, mean SH and SL treatments) and Plumb et al. 2002 (p.26, 32, mean SH and SL treatments).

Species	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness
Run-at-Large Spring	0.76	0.43	11.0
Chinook 1	0.84	0.29	6.7
Steelhead (wild)	0.60	0.27	6.2
Steelhead (hatchery)	0.42	0.18	3.6

3) *Why was the SFO discarded as a design alternative?*

- The SBC concept has *not* been discarded as a possible future design alternative. (The prototype structures themselves have been removed). The SBC partial powerhouse prototype and related structures themselves [designed for a limited life] were evaluated to obtain SFO effectiveness and feasibility data. Variations of this structure (with design refinements based on lessons learned over time and modified for full project application) may have future uses at Lower Granite and / or other projects as it relates to transport / indirect river bypass and direct river bypass.

C) SFO Alternative 2 (path to final design or SFO alternative currently being used): RSW

1) *What modeling and prototype development was done? Present in timeline format.*
    - 2001: RSW Development / Design
    - 2002: RSW "Composite" Test (RSW in combination with features of previously discussed SBC structures)
    - 2003-05: RSW "Stand-Alone" Test
    - 2006: RSW Tests with and without Modified BGS

2) *History of development and testing with the decision path*.
    - Hydraulic evaluations included:
        - Field measurements (ADV and ADCP collected after the construction of the RSW in order to evaluate the hydraulics at the RSW entrance and surrounding area)
        - Numerical models (Conducted to help evaluate different RSW shapes and spill bay location options prior to construction. Also used to analyze hydraulic conditions during operational tests after construction).
        - Physical models (two sectional and one general) to evaluate different design components and project operations.
    - Biological evaluations included:
        - Radio Tracking
        - Hydroacoustics
        - Balloon Tags
        - Acoustic Tags / 3D Tracking
    - Numerical Fish Surrogate (NFS) work to preliminarily evaluate fish behavior and hydraulics overlay for different configurations and project operations.
    - Design considerations
        - Located entrance in area where fish approach project.
        - Used open surface-oriented weir.
        - Designed shaped weir to obtain gradual approach.
        - Designed system with potential for adding BGS.
        - Set bypass flow to high enough level to attract fish, but not cause problems on spillway. (Used 6,000 cfs as minimum flow target which was amount being considered for a full powerhouse system based on Wells Dam SFO discharges).

- Designed RSW for possible long-term use although it was still considered to be a prototype.
- RSW (in combination with entire spillway) needed to have the ability to pass the Probable Maximum Flood (PMF). Lead to the "removable" aspect of the RSW.

- Benefits of RSW over Previous Biological Opinion Spill Operations:
  - Improved in-river fish passage: more fish passed with less water relative to standard gated spill, less delay / higher survival potential.
  - Improved Water Quality: 120% to 110% TDG.
  - Increased Power Revenues.
- Key decision factors
  - RSW improves in-river passage / has benefits over conventional gated spill alone (see previous bullets)
  - Potential to add a BGS with the RSW still exits (Past data from original BGS testing shows promise / awaiting 2006 test results for a reduced depth / more aggressive BGS configuration test).

D) Present status of facility:

1) *Project layout/bypass system configuration: RSW*
   - RSW located in spillbay 1 (See Exhibit 2)
2) *Cost (Design, Construction, Evaluation) for all RSW (Typical for All Applications)*
   - Development / Design: $1 to $2 Million
   - Construction: $12 to $15 Million
   - Biological Evaluations: $2 to $3 Million per year

-
3) *Biological performance*
-

Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
Run-at-Large Spring	2002	nd	nd	0.65	8.7	nd	nd	nd	FCE from Wik memo; FCF Anglea et al. 2003 (p.iv)
	2005	nd	nd	0.31	11.3	nd	nd	nd	Dawson et al. 2006 (p.1)
	2006	nd	nd	no rept yet		nd	nd	nd	
	mean			0.48	10.0				
Run-at-Large Summer	2002	nd	nd	nd	nd	nd	nd	nd	
	2005	nd	nd	0.25	3.3	nd	nd	nd	Dawson et al. 2006 (p.1)
	2006	nd	nd	no rept yet		nd	nd	nd	
	mean			0.25	3.3				
Subyearling Chinook	2005	nd	nd	0.69	nd	0.924	nd	nd	memo from Wik, May 2007 (RSW on)
	2006	nd	nd	0.58	nd	nd	nd	nd	memo from Wik, May 2007 (RSW on with training spill; combined)
	mean	nd	nd	0.64	nd	0.92	nd	nd	
Yearling Chinook	2002	0.6	0.89	0.56	6.5	0.981	nd	0.016	Plumb et al. 2003 (Table 14, p.64, RSW on); Surv . Normandeau et al. 2003 (table 3-1, 48-h, table 3-2, mean for the 3 releases)
	2003	0.49	0.95	0.58	8.3	nd	nd	nd	Plumb et al. 2004 (Table 21, p.67, RSW on)
	2005	nd	nd	0.37	nd	0.984	nd	nd	memo from Wik, May 2007 (RSW on)
	2006	nd	nd	0.30	nd	0.982	nd	nd	memo from Wik, May 2007 (RSW on)
	mean	0.545	0.92	0.45	7.4	0.982	nd	0.016	
Steelhead (wild)	2002	0.72	0.90	0.61	7.1	nd	nd	nd	Plumb et al. 2003 (Table 14, p.64, RSW on); Surv . Normandeau et al. 2003 (table 3-1, 48-h, table 3-2, mean for the 3 releases)
	2003	0.63	0.94	0.67	9.6	nd	nd	nd	Plumb et al. 2004 (Table 21, p.67, RSW on)
	2005	nd	nd	0.49	nd	nd	nd	nd	

	2006	nd	nd	nd	nd	nd	nd	nd	
	mean	0.675	0.92	0.59	8.3				
Steelhead (hatchery)	2002	0.73	0.96	0.62	7.2	nd	nd	nd	Plumb et al. 2003 (Table 14, p.64, RSW on); Surv . Normandeau et al. 2003 (table 3-1, 48-h, table 3-2, mean for the 3 releases)
	2003	0.67	0.91	0.69	9.9	nd	nd	nd	Plumb et al. 2004 (Table 21, p.67, RSW on)
	2005	nd	nd	0.41	nd	nd	nd	nd	
	2006	nd	nd	0.27	nd	0.971			memo from Wik, May 2007 (RSW on)
	mean	0.7	0.94	0.50	8.5	0.971			

4) *Future plans*
   - Potential to add a BGS as part of RSW to gain additional in-river passage.
   - Potential to add a powerhouse surface passage structure (possibly a two-generating unit / single SFO entrance configuration with a BGS) with capability to either transport or bypass fish. (Would require large-scale dewatering capability).

E) Conclusions and lessons learned (from all designs):

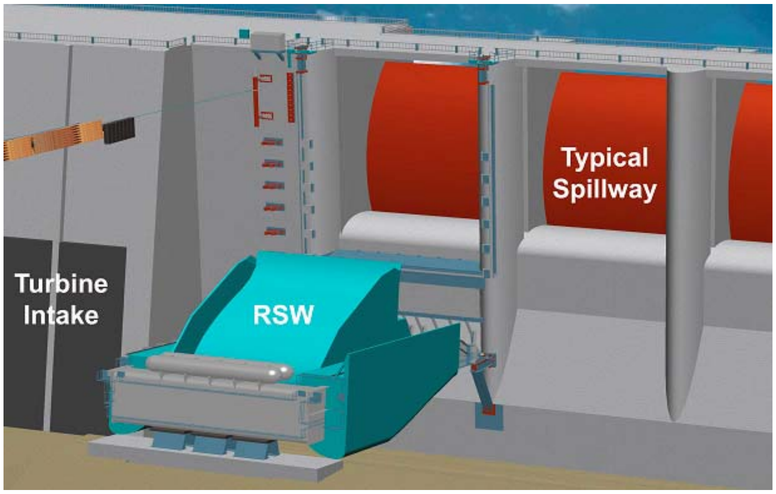
1) *Data gaps identified*
   - Consider long-term biological effects through SFO (direct survival is one indicator / injuries, stress, and delay are others).
   - The amount of SFO attraction flow needed for different applications is still uncertain.
   - The level of gradual shaping (i.e. acceleration criteria) needed for an SFO entrance is not well defined.
   - The use of NFS technology to help assess the potential effectiveness of new SFO configurations and operations is still being evaluated.
2) *Guiding principles/recipes for success*
   - Locate entrances where fish accumulate – either naturally or artificially (entails need for advanced, comprehensive forebay fish behavioral studies).
   - Surface-oriented, free-discharging weir-type entrances and open, natural lighting beyond the weir crest appear to be superior to deep-slot entrances with low entrance velocities.
   - Gradual increasing velocity as flow approaches the weir crest (as with an approach ramp) appears to minimize fish passage delay or entrance rejection.
   - Use of a floating forebay guidance curtain (i.e. BGS) shows promise in improving forebay fish collection performance.
   - Larger bypass flows increase forebay passage performance (in one or two places to attract and capture fish), but do not overcome other deficiencies (such as marginal bypass entrance location).
   - May be better to concentrate entrance flow in one (or a limited number) of openings versus spreading the same total amount over many entrances with lesser discharges.
   - Early investments in research technologies to more precisely describe fish behavior in the forebay hydraulic environment, while initially more costly, will improve the potential for earlier development of a successful SFO.
   - Obtaining detailed project operation information in combination with detailed biological data will result in improved understanding of the finer effects of operational or configuration changes on fish performance.
   - Consider the entire fish passage route (approach conditions to the entrances, actual passage through the structure, and egress conditions) when doing designs / configurations and operation plans.
   - Locating a surface entrance too close to a large structure (say like a BGS) may have negative effects on performance.
   - Operating turbine units at lower levels below powerhouse SFO entrances may improve SFO performance relative to higher turbine discharges.
3) *Pit falls, i.e. what not to do*
   - The reverse curve / "S" shape downstream of the Lower Granite RSW crest created standing waves down the chute. This condition does not appear to injure fish, but should still be minimized if possible.
   - Depending on the results from only one-year of biological tests to make major decisions related to a specific SFO configuration and operation is risky. Results may vary from year to year with different river conditions, etc. plus monitoring and other related problems may occur during the one year test which may compromise the quality of test results.
4) *Absolute requirements*
   - Collect baseline fish behavior and hydraulic data prior to making major investments in construction and testing.
5) *If you had it to do all over again, what would you do differently?*

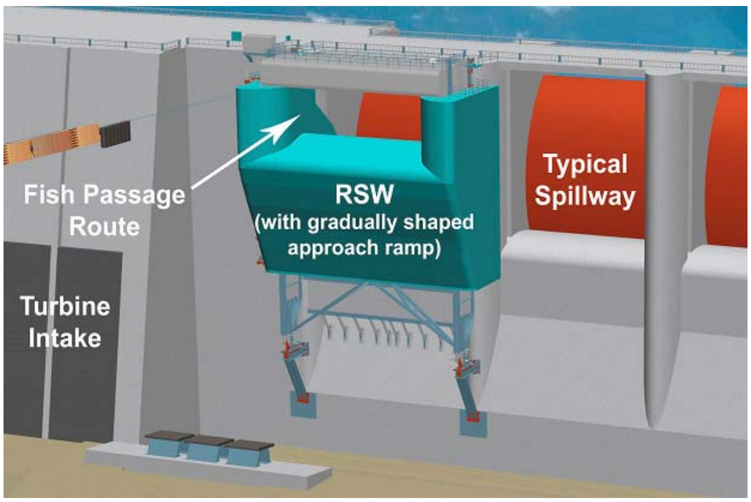
- Attempt to set firmer overall project goals and objectives (including defining what success is) prior to making major decisions. As part of this effort, not only consider fish performance but also other parameters such as water quality and hydropower.
- Need a comprehensive plan (that is agreed on by regional interests) on how to determine the best operation of the project.
- Have a multi-year evaluation plan and stick to it.
- Attempt to set more realistic schedules for accomplishing work.

F) Exhibits:

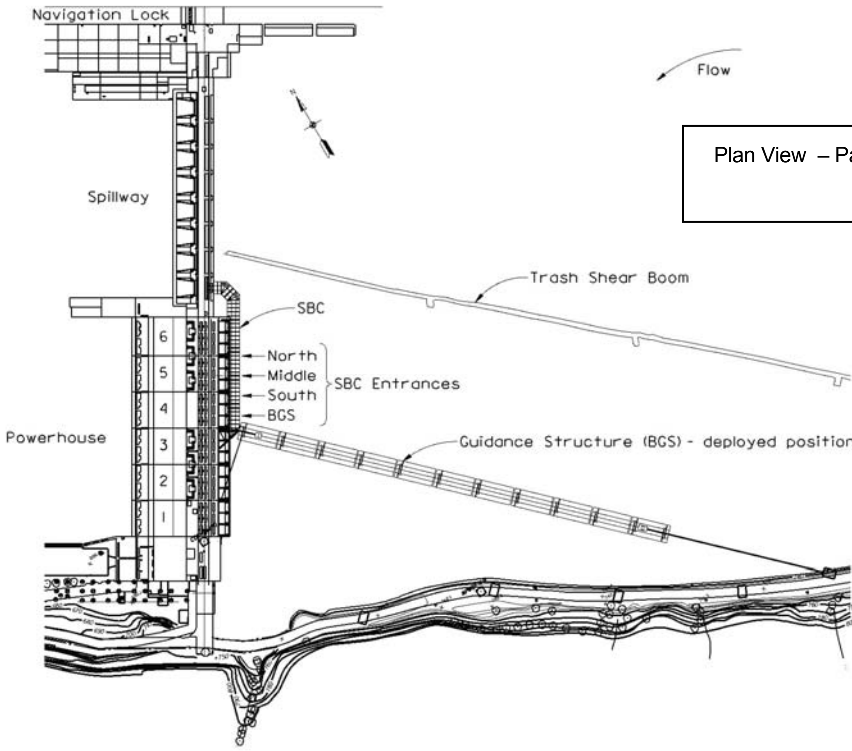
1) Aerial View (Prior to Surface Passage)

2) Current project with SFO

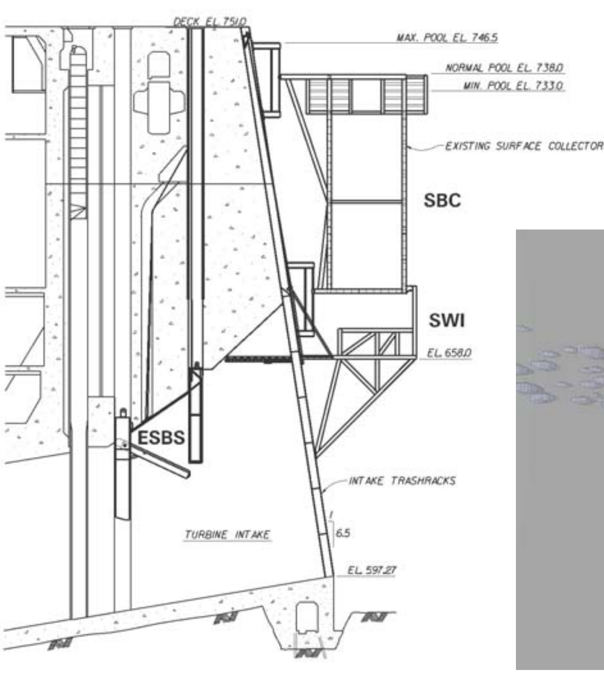

Typical
Spillway
Turbine
Intake
RSW


Fish Passage
Route
RSW
(with gradually shaped
approach ramp)
Typical
Spillway
Turbine
Intake

3) SFO Partial Powerhouse Prototype / Variations for Potential Future Applications



Plan View – Partial Powerhouse SBC with BGS (1998-2000)

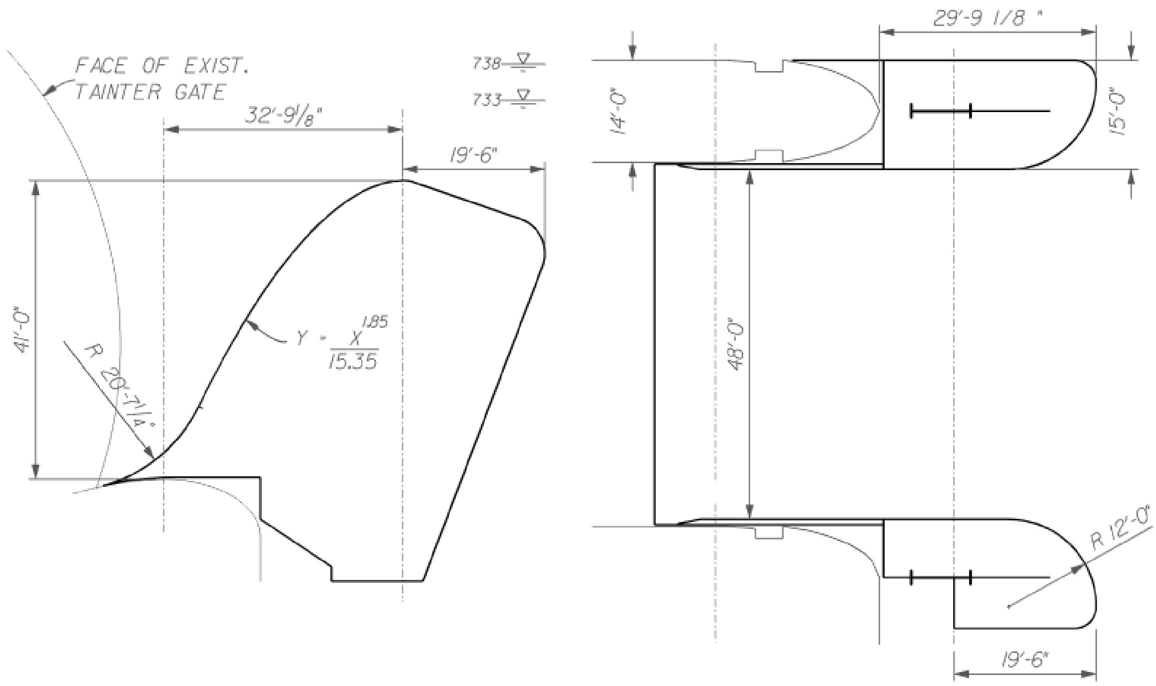


Side View – SBC with Simulated Wells Intake (SWI) (1998-2000)

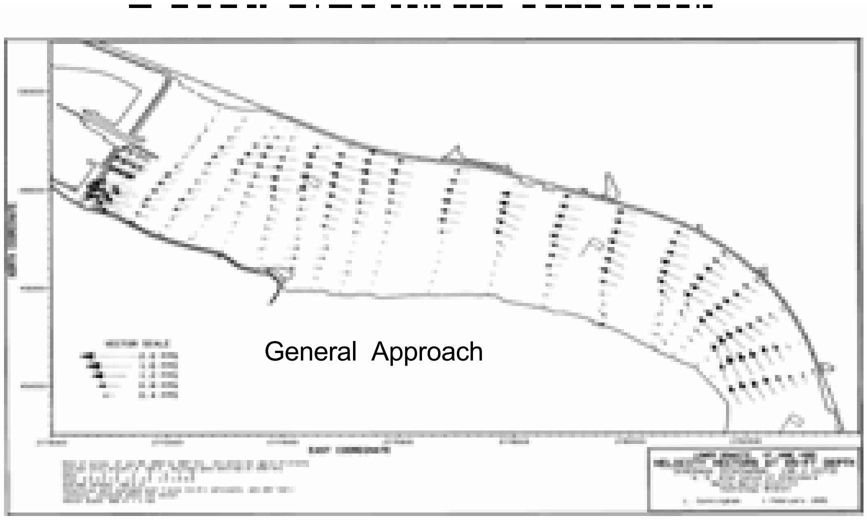
Isometric View of BGS - Underwater View Looking Downstream (1998-2000)

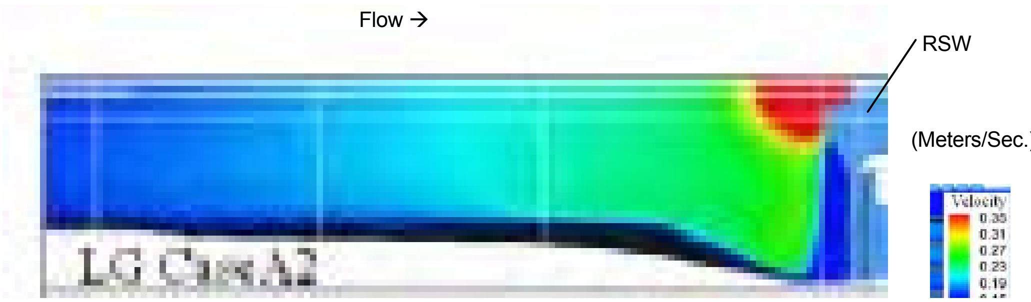
4) Forebay and tailrace bathymetry

5) Current plan and profile of the SFO structures

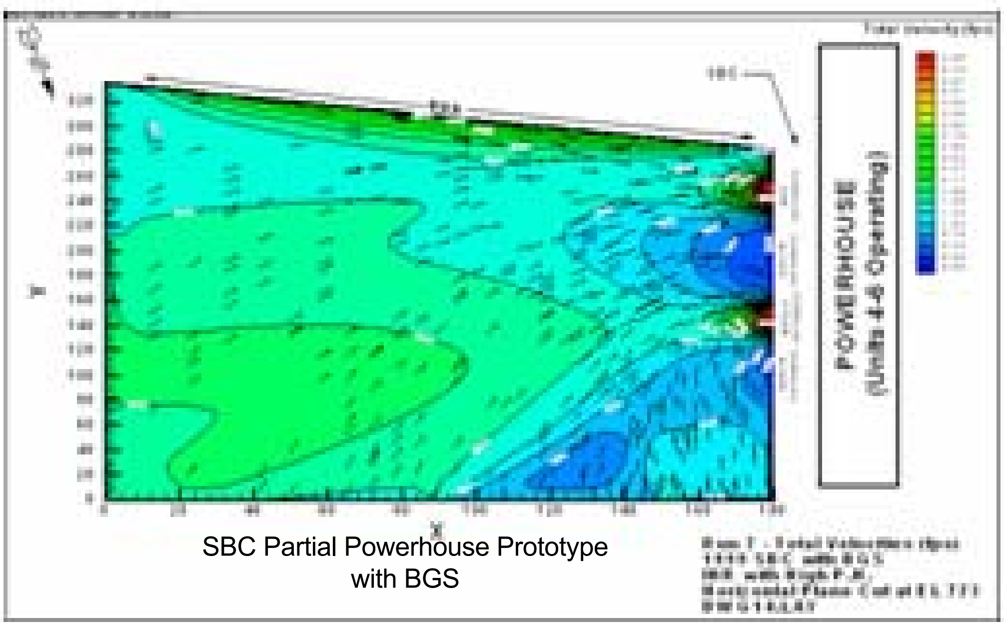


6) Forebay & tailrace flow field.





Cross Section through RSW Centerline



SBC Partial Powerhouse Prototype
with BGS

Project Description

Project: Little Goose Surface Bypass

Presenter: ***Sean Milligan***

Completed By: Sean Milligan

Email: Sean.C.Milligan@usace.army.mil

Phone: (509) 527-7535

Date: 03 Dec 2006

A) Introduction:

1) *Why was SFO considered?*
   - RSW's have been successfully implemented at other lower Snake River dams. Surface oriented spillway passage has been identified by regional fishery agencies as a desirable tool for improving juvenile fish passage and survival.
2) *What initial data kick-started the process?*
   - RSW data from other RSW project (LO-MO, Ice Harbor, Lower Granite)
   - Thalweg closes in on spillway and flow sweeps across the spillway to the powerhouse when high powerhouse flow
   - A shallow area in middle of the tailrace produces many strange eddies, and flow patterns change greatly with operations
3) *What SFOs were investigated (model or prototype)?*
   - RSW, 2 types of ASW

Complete the following for each SFO identified in A.3. that was ultimately discarded

---

B) SFO Alternative 1 (investigated and ultimately discarded): NONE – still in alternative evaluation process

1) *What modeling and prototype development was done? Present in timeline format.*
   -
2) *History of development and testing with the decision path.*
   -
3) *Why was the SFO discarded as a design alternative?*
   -

Complete the following for each SFO identified in A.3. that is currently in use or under development

---

C) SFO Alternative 2 (path to final design or SFO alternative currently being investigated): RSW or ASW – exactly which form of either not yet determined; still under development.

1) *What modeling and prototype development was done? Present in timeline format.*
   - *Note: Dates below beyond the present represent our currently planned schedule and should be considered tentative because the activities haven't occurred yet.*
- Investigation Process: January 2006 - November 2006
  - Investigation process includes CFD modeling, physical modeling (both sectional and general), and biological testing, as well as feasibility-level design efforts.
- Plans and Specs: November 2006 - September 2007
- Solicitation & Award: October 2007 - February 2008
- Construction: March 2008 - March 2009
- Biological Tests: April 2009 - August 2009

2) *History of development and testing with the decision path*.
   - "Candy cane ASW"
     - Development started for LoMo
     - Adjustable crest elevation to allow larger discharge range
     - Fixed piers, but all other pieces come out of the water
     - Transition still upstream of the spillway gate
   - RSW vs ASW2 ("Candy Cane") comparison

  - Fixed crest vs adjustable crest
  - Rotate down into forebay vs. lift out of water
  - Different shape of the zone of influence
  - ASW seems to draw from deeper, but doesn't reach out as far in the forebay near the surface
  - This is more pronounced at lower forebay elevations
  - Capture velocity occurs closer to the U/S end of the piers for the RSW
  - More gradual transition to the crest for the RSW
  - With RSW 7 ft/s reached at pier nose, but with ASW 7 ft/s not reached until inside the piers
- Modified ASW with the intent of:
  - Create approach hydraulics more like RSW
  - Smaller, more compact structure
  - Potentially reduce cost & schedule
  - Safety – less deep diving
  - Reduce projection into forebay
  - Maintain limited adjustability – allows for future flexibility in operations
- Description of modified ASW3
  - Transition downstream of the spillway gate
  - Shorter piers – corbel supports, smaller projection into forebay
  - Smoother transition to existing spillway ogee
  - No side wall transition in the chute – reduce shock waves
  - Limited adjustability
  - Piers are fixed and permanent
  - Do not rotate away like RSW
  - Pier extensions have symmetric shape to avoid impacting adjacent bay flow capacity
- Surface Bypass (RSW or ASW) bay selection
  - Choose bay 1, until reason to do otherwise
  - 2006 biological testing will provide approach and survival data
  - Lower Granite RSW provides precedence to locate closer to the powerhouse.
  - No Spillway deflector in bay 1 creates opportunity for fish friendly deflector
  - Bay 1 can be operated with less training spill to provide favorable tailrace conditions.
  - Location of the debris boom or a BGS bay be an issue
- Tailrace hydraulics
  - Tailrace hydraulics also influences bay selection & spill patterns
  - Primary issues are:
    - Favorable adult fish passage, especially along south shore
    - Favorable juvenile fish egress
    - Avoid or minimize major eddies – powerhouse & north shore
    - Powerhouse flow entrainment into spillway stilling basin – impacts dissolved gas production

D) Present status of facility: Still under development; no specific design details, cost, or biological performance information available yet.

1) *Project layout/bypass system configuration:*
2) *Cost (Design, Construction, Evaluation)*
3) *Biological performance*
4) *Future plans*

E) Conclusions and lessons learned (from all designs): Still under development.

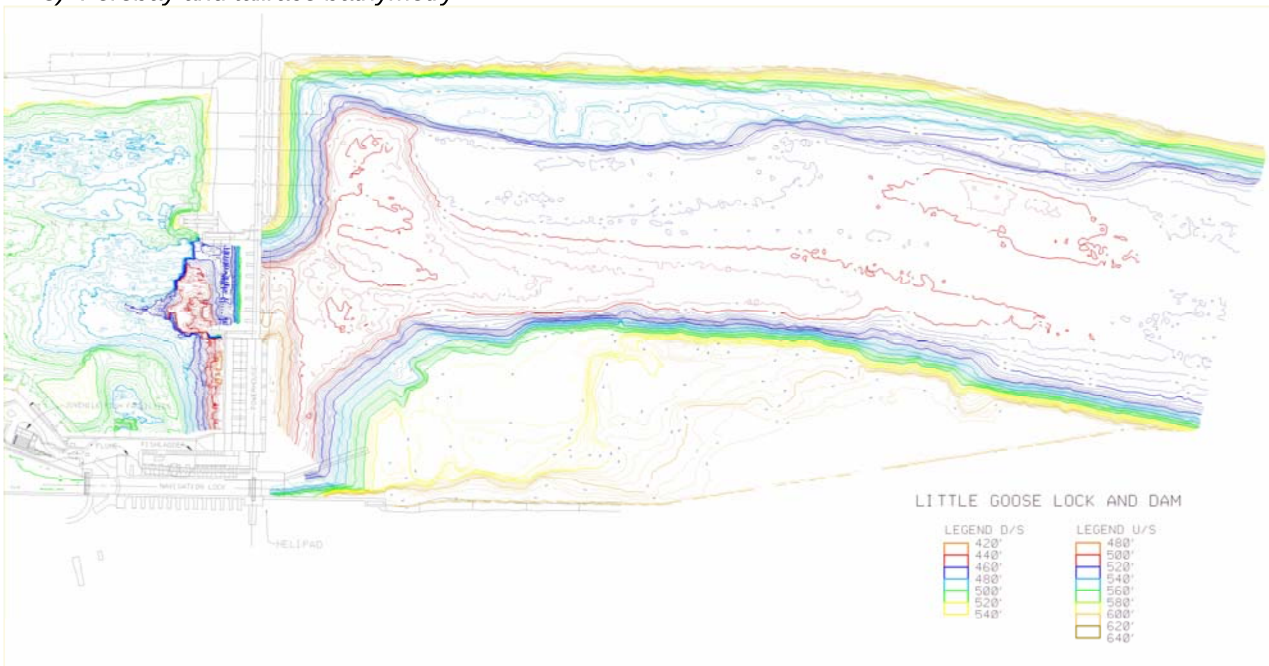
1) *Data gaps identified*
2) *Guiding principles/recipes for success*
3) *Pit falls, i.e. what not to do*
4) *Absolute requirements*
5) *If you had it to do all over again, what would you do differently?*

F) Exhibits:

1) Arial photo

2) Current project layout with SFO **Not yet determined**.

3) Forebay and tailrace bathymetry



4) Current plan and profile of the SFO structure **Not yet determined.**

5) Forebay & tailrace flow fields **Not available with SFO as it is still under development**.

General Stats:

- Normal Forebay 633 to 638
- ~100' Gross Head
- 8 spillbays (length 512')
- 6 powerhouse units (length 656')
- 11-18 kcfs capacity per powerhouse unit (within 1% of peak efficiency)

Project Description

Project: Lower Monumental Surface Bypass

Presenter: ***Ken Hansen***

Completed By: Ken Hansen

Email: ken.e.hansen@usace.army.mil

Phone: 509-527-7533

Date: 12-8-06

A) Introduction:

1) *Why was SFO considered?*
   - Regional state and Federal fishery agencies have put an emphasis for implementing RSWs on the lower Snake River projects.
   - Improve the survival of juvenile salmoids passing the project.
   - Similar information as presented for the Ice Harbor RSW (see Ice Harbor Project sheets from Lynn)
2) *What initial data kick-started the process?*
   A successful prototype RSW was installed at Lower Granite Lock and Dam in May of 2001. The Lower Granite RSW performance demonstrated the ability to pass more fish through the project in a safer and more cost efficient manner as compared to the existing conventional spillbays. This success led to the development of an Ice Harbor RSW. The Lower Monumental RSW was patterned from these prototype systems as part of a multi-year development schedule for installation of RSWs.
3) *What SFOs were investigated (model or prototype)?*
   - RSW

Complete the following for each SFO identified in A.3. that is currently in use or under development

---

B) SFO Alternative 2 (path to final design or SFO alternative currently being investigated): RSW

1) *What modeling and prototype development was done? Present in timeline format.*
   - Investigation Process: July 2005 - March 2005
   - Plans and Specs: January 2005 - November 2005
   - Solicitation: January 2006
   - Award: May 2006
   - Construction: May 2006 - March 2007
   - Biological Tests: April 2007 - August 2007
2) *History of development and testing with the decision path*.
   - Investigation process:
     - Applied available biological data from the project and other relative information.
       - Baseline telemetry data to get forebay fish approach patterns and passage routes.
       - Spillway injury tests.
     - Lessons learned from prior prototype testing of similar projects.
       - From Lower Granite to Ice Harbor: removed reverse curve to minimize the standing wave
       - From Ice Harbor to Lower Monumental:
         - Used a more aggressive slope, because of geometric constraints.
         - Tried to increase the radius of the RSW, but caused cavitation.
     - Analysis of hydraulic conditions using physical and analytical models.
     - Attempted to apply results from a fish behavior model (NFS). Challenges with converting model to use unstructured grids.
   - Bay selection process:
     - Biological testing showed bay 8 with greater concentration of fish.
     - 2005 biological tests show less injury in bay 8 than in bay 7.
     - Lower Granite RSW provides precedence to locate closer to the powerhouse.
     - Forebay hydraulics bias bay 8 with the thalweg location and flow approaching powerhouse.
     - Spillway deflector elevation is 2-feet lower in bay 8 than in bay 7.
     - Bay 8 can be operated with less training spill to provide favorable tailrace conditions.

- Stilling basin is 2-feet shallower in bay 7.
- Minimal powerhouse entrainment observed in the general model.
- Easier Construction with attaching due to coffer cells in front of bay 7.
- Chose bay 8
- Entrance flow field
  - Centerline Velocity at Face of Piers is 6.2 to 7.4 fps
  - Centerline Velocity Gradient within 20 feet of entrance varies between approximately 0.12 to 0.25 fps/ft
  - Centerline Velocity Gradient at Capture Velocity (7 fps) is approximately 0.27 to 0.33 fps/ft
- Test Treatments: 2006 Spring
  - ~ 25 kcfs bulk spill pattern to simulate RSW (gas cap controlled)
  - Survival and passage routes
  - 2 species – first time for steelhead
- Test Treatments: 2006 Summer
  - 17 kcfs bulk spill pattern to simulate RSW
  - Survival and passage routes

C) Present status of facility:

1) *Project layout/bypass system configuration:*
   - RSW in construction phase with plans to be in operation spring 2007.
2) *Cost (Design, Construction, Evaluation)*
   - Construction: $14.7M
   - Design $1M
   - M&E $4M
3) *Biological performance*
   - Not available at this time
4) *Future plans*
   - Development of 2007 Test Treatments
     - Optimize Spill for both forebay attraction and tailrace egress
     - Evaluate Powerhouse Priorities
     - Address navigation issues

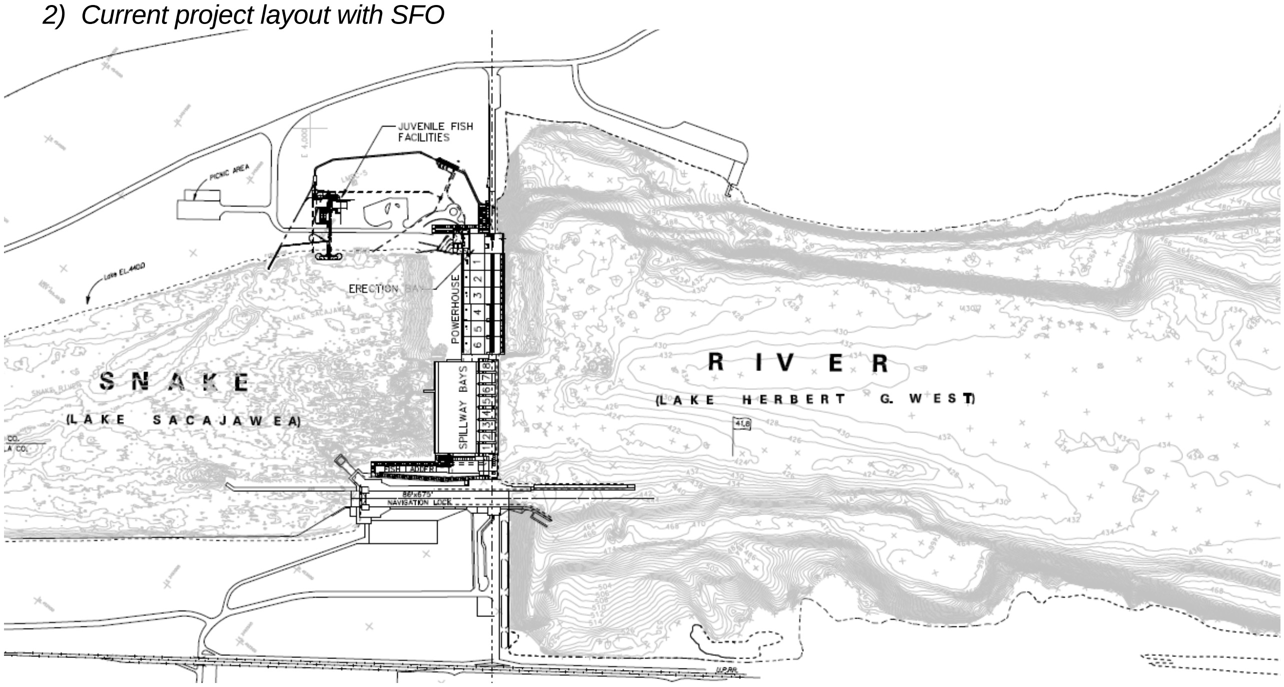
D) Conclusions and lessons learned (from all designs):

1) *Data gaps identified*
   - Not available at this time
2) *Guiding principles/recipes for success*
   - Build on precedence of other RSW and similar projects.
3) *Pit falls, i.e. what not to do*
   - Not available at this time
4) *Absolute requirements*
   - Operation by 2007.
5) *If you had it to do all over again, what would you do differently?*
   - Not ask for non-participating agency approval on bay selection.

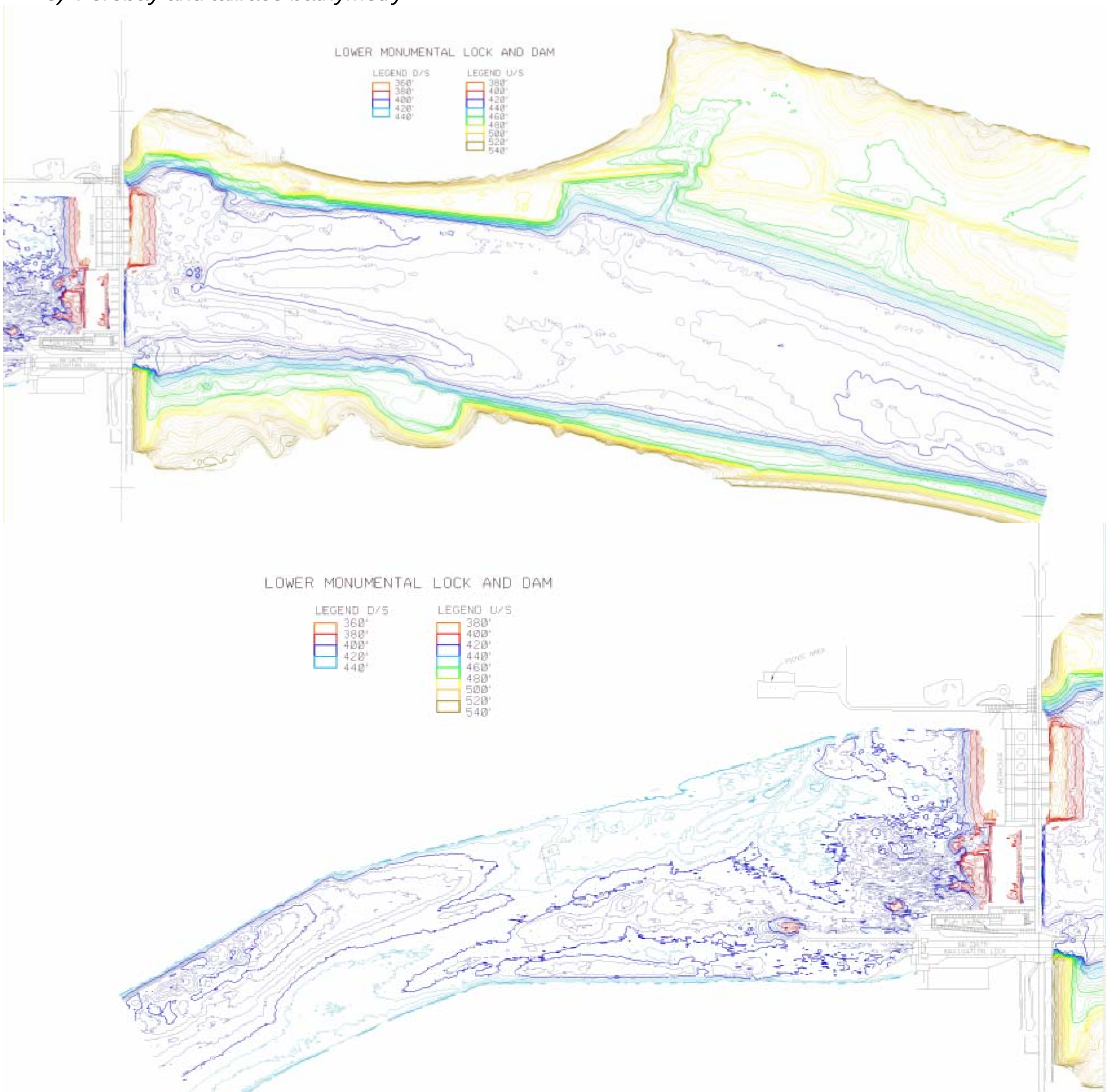
E) Exhibits:

1) *Arial photo* (in presentation)

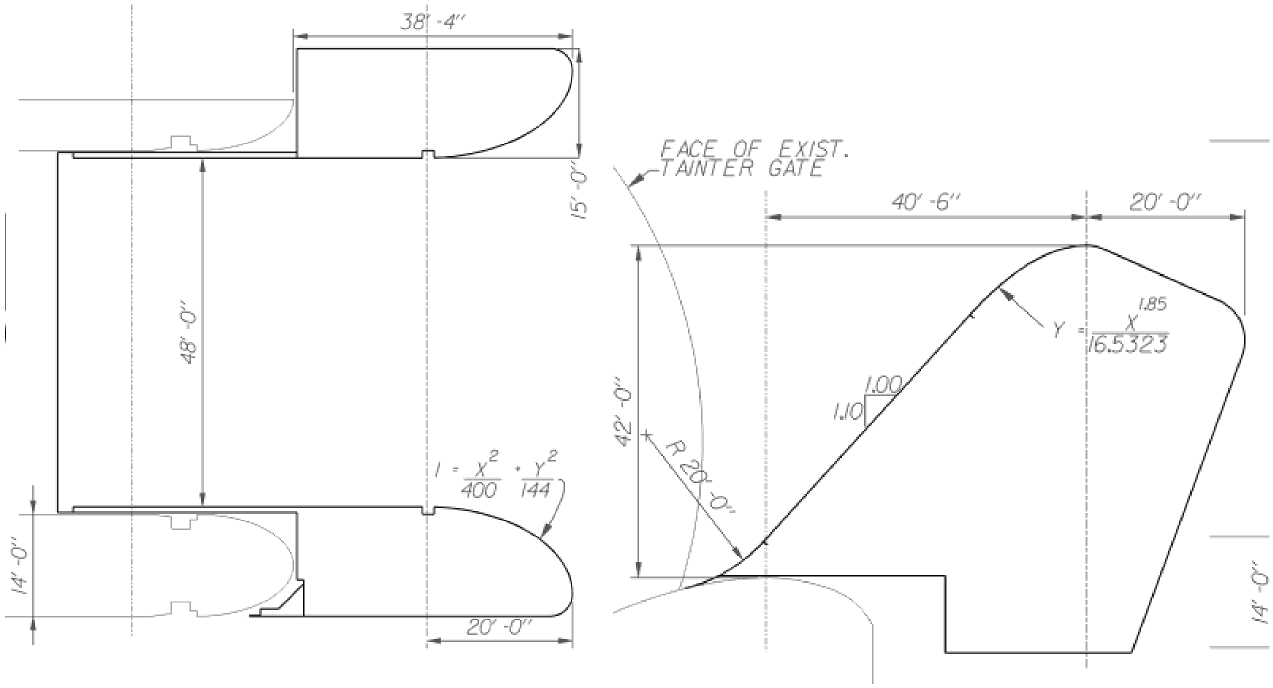
2) *Current project layout with SFO*



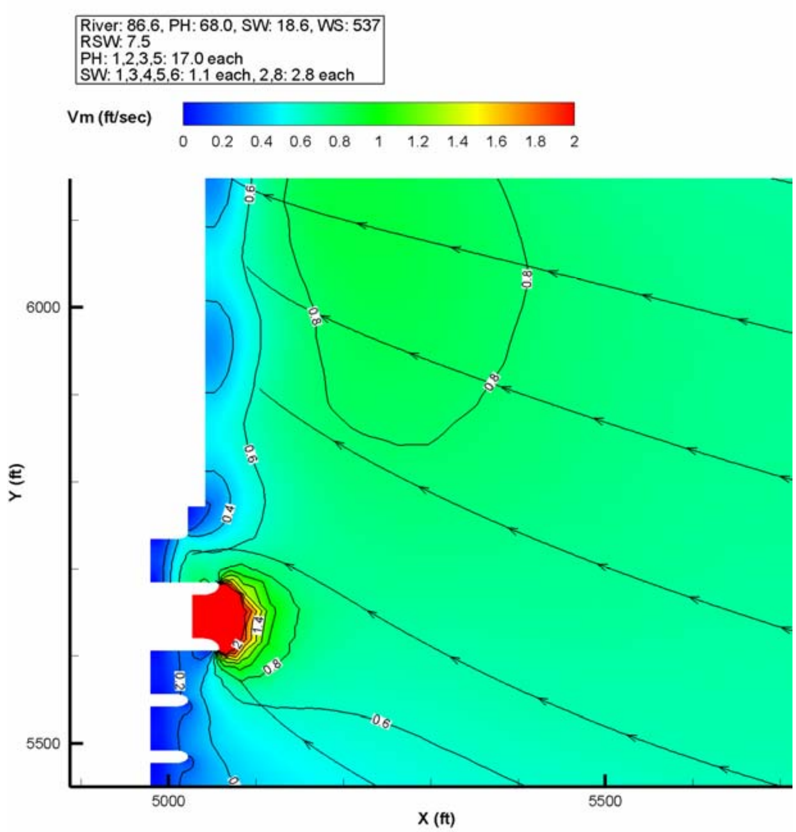
3) Forebay and tailrace bathymetry

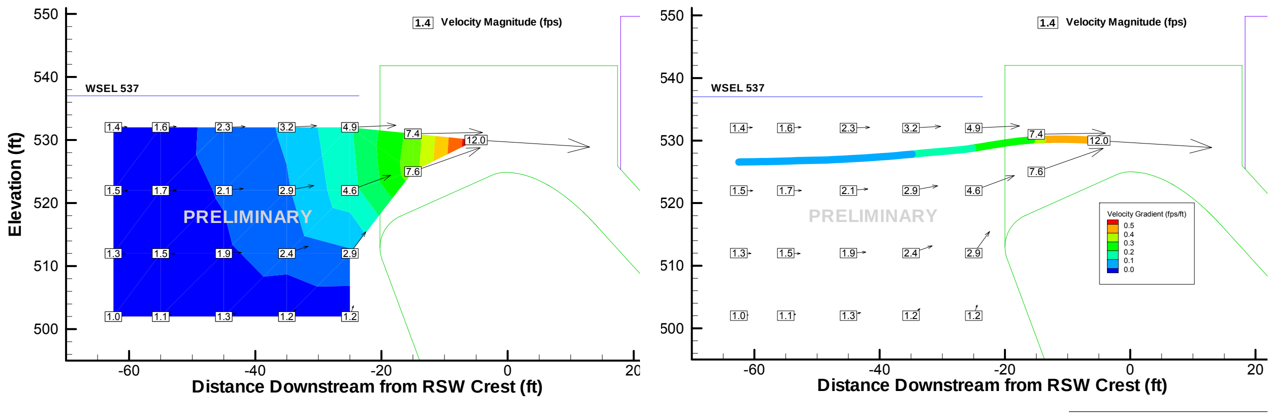


4) Current plan and profile of the SFO structure



5) *Forebay flow fields* (no data available for tailrace flow field)





General Stats:

- Normal Forebay 537 to 540
- ~100’ Gross Head
- 8 spillbays (length 512’)
- 6 powerhouse units (length 656’)
- 18 kcfs capacity per powerhouse unit

Project Description

Project: Ice Harbor Surface Bypass

Presenter: ***Lynn Reese***

Completed By: **Lynn Reese / Tim Wik**

Email: **lynn.a.reese@usace.army.mil**

tim.o.wik@usace.army.mil

Phone: **509-527-7531 (Reese)**

509-527-7206 (Wik)

Date: **October 30, 2006** (modified 1/4/07 GEJ)

A) Introduction:

1) *Why was SFO considered?*
   - Successful RSW performance data from Lower Granite.
   - SFO was one of the technologies identified within the Corps' Lower Snake River Feasibility Study (under Major System Improvements) that might be used to improve juvenile fish passage through the hydropower corridor. Evaluating the effectiveness and feasibility of SFO technology was one of the goals of this study. The focus for Ice Harbor was for in-river passage only since this project currently does not have transport capability.
   - Primary goal for SFO was to increase juvenile fish passage (and ultimately higher survival) through non-turbine routes by:
     - Lowering stress and injury
     - Reducing delay
   - SFO on spillway routes might also allow for reduced voluntary spill.
     - Improve water quality by reducing total dissolved gas (TDG) levels
     - Increase power revenues.
2) *What initial data kick-started the process?*
   - Old sluiceway passage efficiency data from the 1980s at Ice Harbor Dam.
   - RSW design and performance data from Lower Granite.
   - Collected Ice Harbor baseline radio telemetry and hydroacoustic data to get forebay approach patterns and dam passage.
   - Used previously collected forebay hydraulic field data (from sediment range studies) as a starting point for calibration / verification of hydraulic models.
3) *What SFOs were investigated (model or prototype)?*
   - Sluiceway at the powerhouse (1982-1995)
   - Sluiceway with reconfigured entrances using a prototype vertical slot structures (1995)
   - Removable Spillway Weir (RSW) Prototype (2005 to present)
     - With and Without BGS addition (model study only)

B) **SFO Alternative: Sluiceway**

1) *History of development and testing with the decision path.*
   - The sluiceway at Ice Harbor was operated to bypass juvenile salmonids in the 1980s and early 1990s because fisheries and project managers recognized that it served as a non-turbine passage route for downstream migrants.
   - The sluiceway entrances had chain gates with a maximum discharge of about 2,700 cfs. Typically three gates were opened. The sluiceway channel spanned the powerhouse before emptying straight down into a conveyance channel to an outfall in the tailrace.
   - Estimating SFO fish collection efficiency for various entrance conditions was a primary objective in sluiceway at Ice Harbor. Johnson, et al. (1983) compared a three-gate vs. six-gate configuration for the sluiceway at the same discharge level (2,700 cfs). They found that "sluice gate configurations had no significant effect on the sluiceway efficiencies...suggests that the 6-gate-configuration's potential advantage in efficiency, (i.e., broader range of gate availability) is equivalent to the 3-gate-configuration's potential advantage in efficiency (i.e., high "attraction" current)." This is an important observation because it demonstrates the tradeoff between number of entrances and entrance velocity for a given Q is equivalent in terms of SFO efficiency.

- See the following table for efficiency and effectiveness data from the 1980s.

Species	Study-Year	Fish Collection Efficiency	Fish Collection Effectiveness
Run-at-Large Spring	1982	0.13	8.7
	1983	0.30	13.6
	1986	0.50	22.9
	1987	0.34	6.8
	Mean	0.32	13.0

2) *What modeling and prototype development was done? Present in timeline format.*
    - No modeling or prototype work was done on the sluiceway. The sluiceway was an original structure to pass ice and trash at the dam.
3) *Why was the SFO discarded as a design alternative?*
    - The sluiceway was closed in 1996 because managers decided that a submersible traveling screen system in the turbine intakes was the preferred juvenile salmonid protection system at Ice Harbor. Building this screen bypass system necessitated closing off the sluiceway in 1996. Before doing that though, the Corps performed SFO prototype research at Ice Harbor in 1995.

C) **SFO Alternative: Reconfigured sluiceway entrances**

1) *History of development and testing with the decision path.*
    - The goal of this effort was to make use of the last year of availability of the IHR sluiceway to do SFO development tests and apply the results to SFO development at Lower Granite, where prototype tests would start in 1996. Thus, Ice Harbor provided a secondary SFO development test site where results are applied to other locations.
    - In 1995 the SFO strategy at Ice Harbor powerhouse was comprised of surface sluice with and without reconfigured entrances. Reconfigured entrances that had vertical slots were retrofit on the dam at Turbine Intakes 1A and 4B. These SFO prototype structures deepened the area of influence of a sluicegate; i.e., water entering the vertical slots emptied into the sluiceway. In addition, a regular sluicegate with “surface sluice skim” was operated. At the spillway, surface spill was compared to regular deep spill. Overall there were four SFO test conditions at the powerhouse (from BioSonics 1996):
        - Vertical slot 1A narrow (4 ft wide and 40 ft deep) at 2 fps entrance velocity
        - Vertical slot 1A narrow at 4 fps entrance velocity
        - Vertical slot 4B wide (6 ft wide and 40 ft deep) at 4 fps entrance velocity
        - Sluicegate 2B (20 ft wide and 6 ft deep) at 7.5 fps
    - The 1995 prototype SFO conditions were evaluated using radio telemetry and hydroacoustics. Swan, et al. (1996) found that few radio-tagged chinook salmon passed into the vertical slot at 1A under any condition. Similarly, comparison of wide (4B) vs. narrow (1A) was not possible because of too few detections. Of the 53 radio-tagged chinook known to have entered the sluiceway, 57% used the regular surface skim sluicegate at 2B. Similar surface preference was observed at the spillway. The authors said, “...radio-tagged juvenile salmonids preferred a surface collector design which utilized a surface skim rather than a deep draw.” This observation was essentially confirmed by BioSonics’ (1996) fixed-location hydroacoustic study.
    - BioSonics (1996) noted that all SFO configurations were very effective and that regular sluicegate surface skim “consistently had the highest fish passage rates and bypass efficiencies...” The experimental design in either study, however, did not allow the researchers to statistically separate effects of location (1A, 2B, 4A) from SFO configuration. Entrance efficiency (percentage of fish that enter the SFO out of the total “available”, i.e., the total that encounter the SFO) was not estimated in the 1995 hydroacoustic or radio-telemetry studies. In conclusion, the surface sluice SFO entrance condition appeared promising and was more effective than spill.
2) *What modeling and prototype development was done? Present in timeline format.*

- No modeling was done before the construction and installation of the reconfigured sluiceway entrance structures because this effort was fast-tracked to installation as part of the Corps' Surface Bypass Program, which was initiated one year earlier in 1994.
- Hydraulic data were collected in a physical scale model (1:25) during summer 1995.

3) *Why was the SFO discarded as a design alternative?*
   - A key result from SFO research at Ice Harbor Dam in 1995 was that it appeared an unmodified sluice entrance had apparently higher passage rates and bypass efficiencies than the sluice gate with a reconfigured vertical slot entrance. The SFO strategy of installing reconfigured sluiceway entrances did not apparently enhance sluiceway performance as they were designed to.

D) SFO Alternative 1 (path to final design or SFO alternative currently being used): RSW

1) *What modeling and prototype development was done? Present in timeline format.*
   (Note: Pre-test work completed at Ice Harbor [1994-1996] to gain insights for SFO work at Lower Granite also provided some insights for work at Ice Harbor. In particular, it was found that a surface skimming configuration at Ice Harbor was noticeably more efficient than gated spill).
   - 2002-2003: Baseline Biological Data
   - 2003-2004: RSW Development / Design / Construction
   - 2006-2006: RSW Testing
2) *History of development and testing with the decision path*.
   - Hydraulic evaluations included:
     - Numerical models (Conducted to help evaluate different RSW shapes and spill bay location options prior to construction. Also used to analyze hydraulic conditions during operational tests after construction).
     - Physical models (one sectional and one general) models to evaluate different design components and project operations).
   - Biological evaluations included:
     - Radio Tracking
     - Hydroacoustics
     - Balloon Tags
   - Numerical Fish Surrogate (NFS) work to preliminarily evaluate fish behavior and hydraulics overlay for different configurations and project operations.
   - Design considerations
     - Modified the previous Lower Granite RSW to apply at Ice Harbor. Specifically changed the shaping downstream of the crest to minimize the development of standing waves.
     - Located entrance in area where fish approach project.
     - Used open surface-oriented weir.
     - Designed shaped weir to obtain gradual approach.
     - Designed system with potential for adding BGS.
     - Set bypass flow to high enough level to attract fish, but not cause problems on spillway. (Used 7,500 cfs as minimum flow target which was amount tested during previous successful Lower Granite RSW testing).
     - Designed RSW for possible long-term use although it was still considered to be a prototype.
     - RSW (in combination with entire spillway) needed to have the ability to pass the Probable Maximum Flood (PMF). Lead to the "removable" aspect of the RSW.
   - Benefits of RSW over Previous Biological Opinion Spill Operations:
     - Comparable in-river fish passage with significantly less water relative to previous standard gated spill.
     - Potential for improved water quality (lower TDG) depending on spill level used with RSW.
     - Potential for increased power revenues depending on spill level used with RSW.
   - Key decision factors
     - RSW has benefits over conventional gated spill alone (see previous bullets)
     - Potential to add a BGS with the RSW exits (Past data from Lower Granite original BGS testing shows promise / awaiting 2006 Lower Granite test results for a reduced depth / more aggressive BGS configuration test).

E) Present status of facility:

1) *Project layout/bypass system configuration: RSW*
   - RSW located in spillbay 2 (See Exhibit 2)
2) *Cost (Design, Construction, Evaluation) for all RSW (Typical for All Applications)*
   - Development / Design: $1 to $2 Million
   - Construction: $12 to $15 Million
   - Biological Evaluations: $2 to $3 Million per year
3) *Biological performance* (from Axel et al. 2006 and Preliminary Data report by NOAA submitted to CENWW)

Species	Year	FCE	FCF	Direct Survival	Data Source
Run-at-Large Spring	2005	0.28			memo from Wik, May 2007 (RSW on)
	2006				
	mean	0.28			
Run-at-Large Summer	2005	0.38			memo from Wik, May 2007 (RSW on)
	2006				
	mean	0.38			
Subyearling Chinook	2005	0.60		0.970	memo from Wik, May 2007 (RSW on)
	2006	0.68		0.980	memo from Wik, May 2007 (RSW on)
	mean	0.64		0.98	
Yearling Chinook	2005	0.29	3.1	0.970	Axel et al. 2006
	2006	0.51	7.3	0.947	memo from Wik, May 2007 (RSW on w/ 30-40% spill)
	mean	0.40	5.20	0.96	
Steelhead	2005	0.47	5.2	0.985	Axel et al. 2006
	2006	0.38	5.4	1.017	memo from Wik, May 2007 (RSW on w/ 30-40% spill)
	mean	0.42	5.30	1.00	

4) *Future plans*
   - Potential to add a BGS as part of RSW to gain additional in-river passage with less spill.
   - Potential to modify RSW / spillway chute and deflector to reduce injury.

F) Conclusions and lessons learned (from all designs):

1) *Data gaps identified*
   - Consider long-term biological effects through SFO (direct survival is one indicator / injuries, stress, and delay are others).
   - The amount of SFO attraction flow needed for different applications is still uncertain.
   - The level of gradual shaping (i.e. acceleration criteria) needed for an SFO entrance in not well defined.
   - The use of NFS technology to help assess the potential effectiveness of new SFO configurations and operations is still being evaluated.
2) *Guiding principles/recipes for success*
   (Note: Similar information as presented for the Lower Granite RSW [See Lower Granite Project sheets] plus additional information below).
   - The volume of spill occurring with the RSW will have a direct effect on RSW performance. In addition, how you operate spill bays adjacent to the RSW may have negative impacts on RSW performance. (Additional insights will be gained after the evaluation of 2006 field test data).
3) *Pit falls, i.e. what not to do*
   (Note: Similar information as presented for the Lower Granite RSW [See Lower Granite Project sheets] plus additional information below).

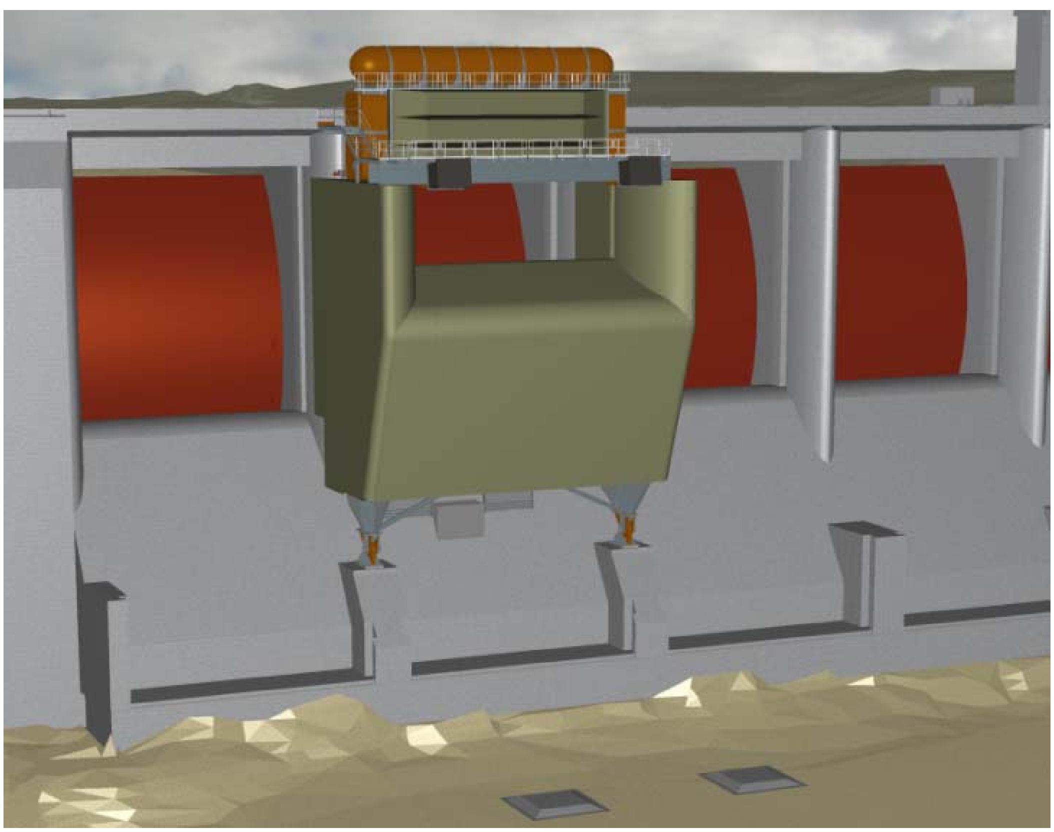
4) *Absolute requirements*
(Note: Similar information as presented for the Lower Granite RSW [See Lower Granite Project sheets]).

5) *If you had it to do all over again, what would you do differently?*
(Note: Similar information as presented for the Lower Granite RSW [See Lower Granite Project sheets]).

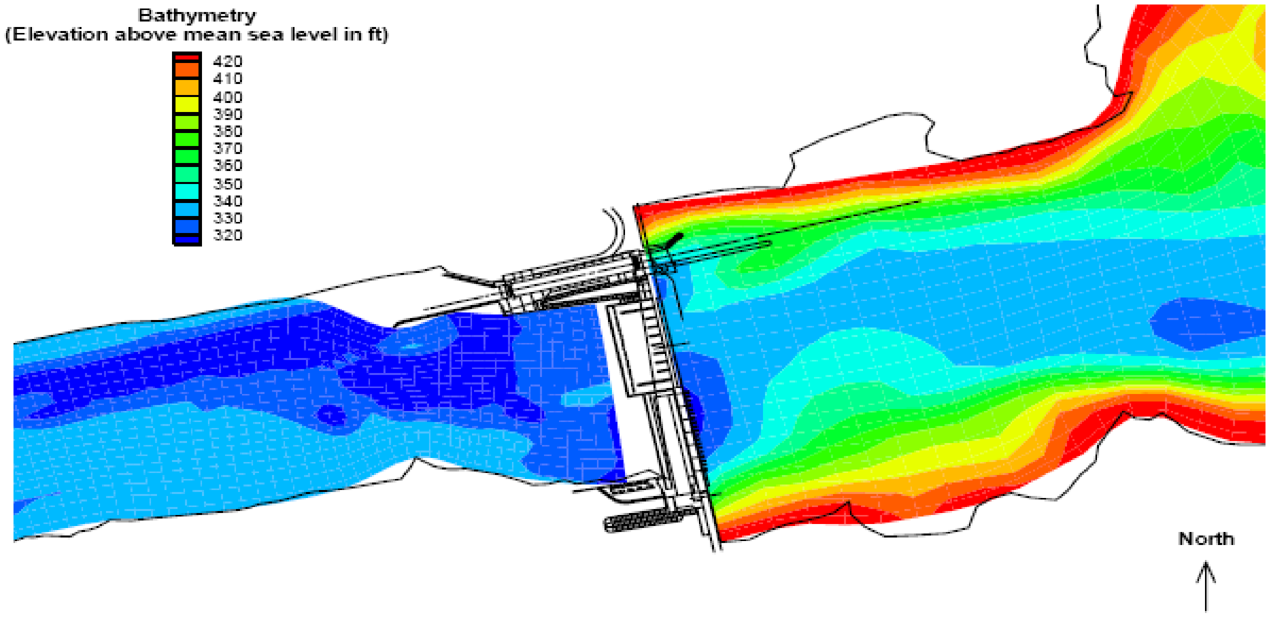
F) Exhibits:

1) Aerial View (Prior to Surface Passage)

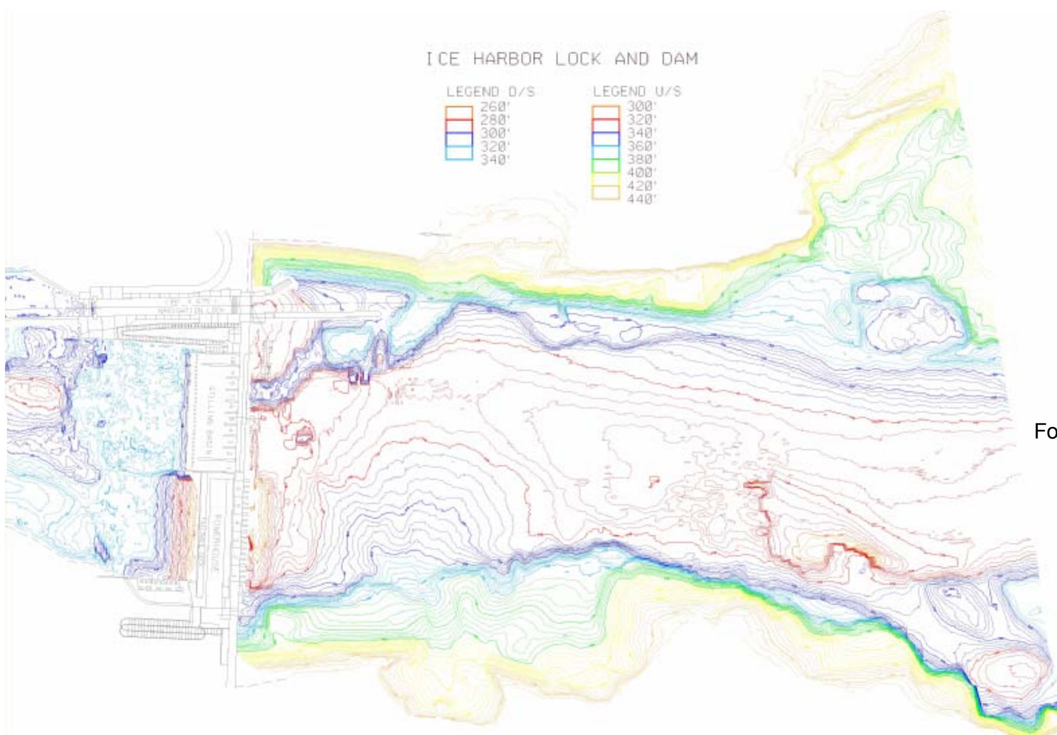
2) Current project with SFO



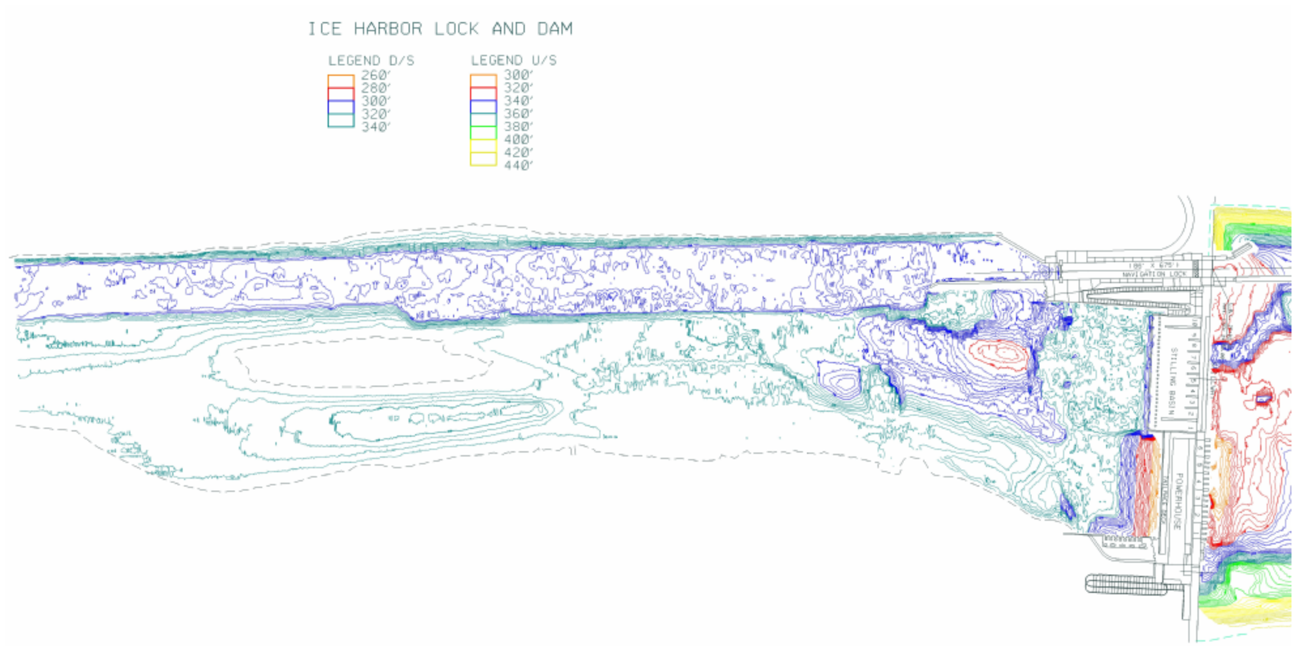
3) Forebay and tailrace bathymetry



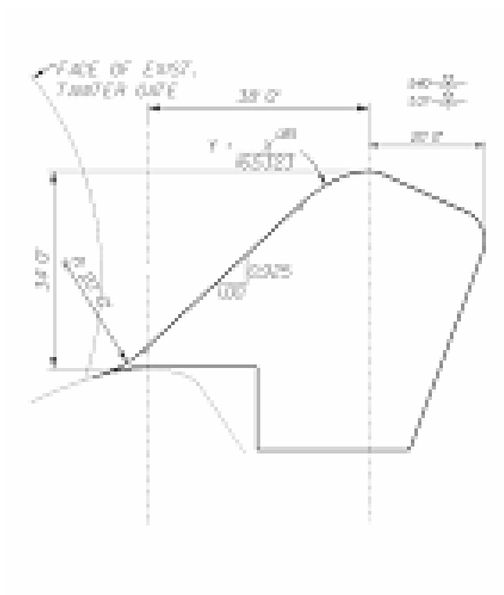
Tailrace



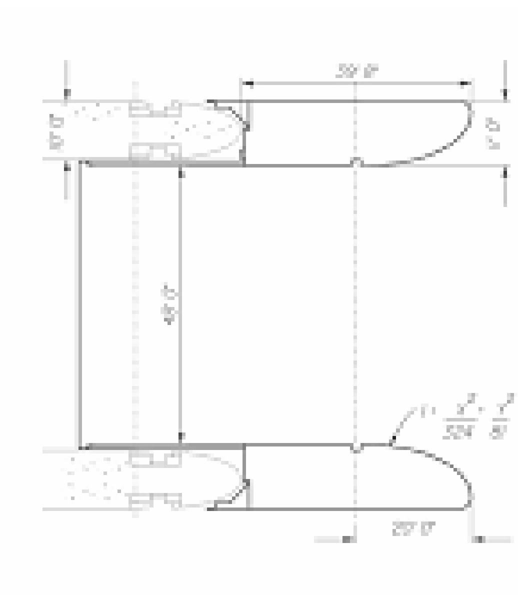
Forebay



4) Current plan and profile of the SFO structures

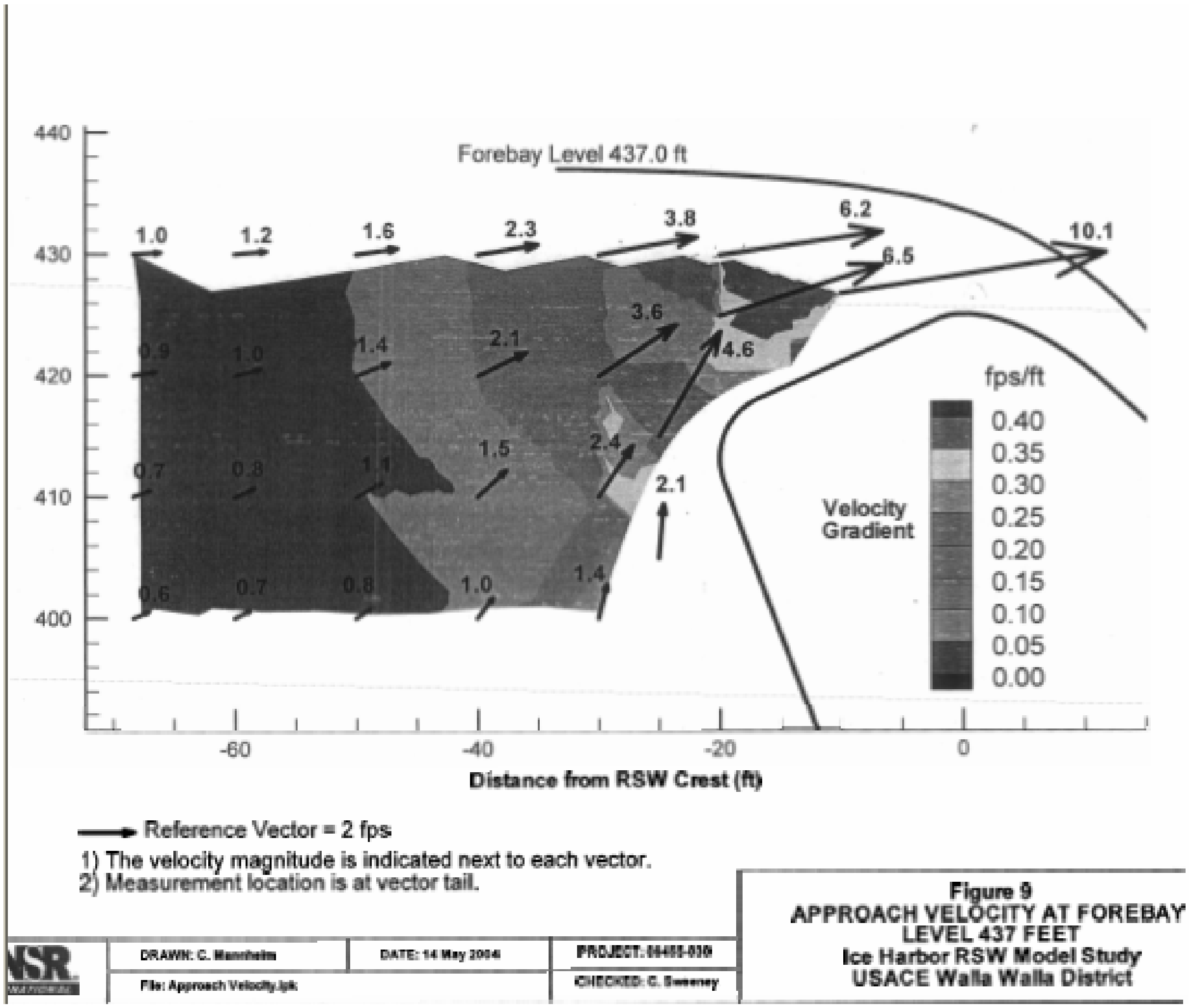


Section



Profile

5) Forebay flow field.



Project Description

Project: McNary Surface Bypass

Presenter: ***Dan Feil***

Completed By: Dan Feil, Ken Hansen

Email: dan.h.feil@usace .army.mil, ken.e.hansen@usace.army.mil

Phone: Dan – 509 527-7295, Ken – 509 527-7533

Date: December 1, 2006

A) Introduction:

1) *Why was SFO considered?*
   - Endangered Species Act: Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp).
   - Improve the survival of juvenile salmonids passing McNary Dam.
     - Corps' target – 96.3% dam survival of yearling chinook salmon.
     - FCRPS BiOp remand could result in project specific juvenile salmonid survival performance standards.
2) *What initial data kick-started the process?*
   - McNary SFO brainstorming workshop held in July 2005.
     - Identified several spillway, non-overflow section, and powerhouse alternatives.
     - Focused on spillway to develop relatively low-cost alternative to test SFO concept.
3) *What SFOs were investigated (model or prototype)?*
   - One or more TSWs will be constructed in late 2006 and installed in spring 2007 for biological evaluation.

Complete the following for each SFO identified in A.3. that was ultimately discarded

---

B) SFO Alternative 1 (path to final design or SFO alternative currently being investigated): TSW

1) *What modeling and prototype development was done? Present in timeline format.*
   - Walla Walla District contracted with ENSR to construct and test a 1:25 scale sectional spillway model.
   - Testing is on-going while investigation the feasibility of other alternatives.
2) *History of development and testing with the decision path*.
   - Conducted 2006 forebay behavior study to collect info on fish approach and passage patterns to help place SFO structure(s).
   - Conducted physical modeling exercises and settled on Temporary Spillway Weir (TSW) to test SFO concept at McNary Dam.
     - TSW designs are complete.
     - Contract currently being advertised.
     - Two-piece structure that utilizes spillbay emergency and operating gates slots.
     - Nappe intersects ogee above tailwater.
     - Design Q – ~10.0 kcfs @ 340.0 pool elevation.
   - Test different configurations of the TSW to better understand requirements for final installation.

C) Present status of facility:

1) *Project layout/bypass system configuration:*
   - TSW is under construction. The feasibility of other alternatives are being investigated in preparation for results of biological testing.
2) *Cost (Design, Construction, Evaluation)*
   - Design: $197K
   - Construction: $2.7M (TSW2, TSW1)
   - Evaluation: $5M (all routes incl.))
3) *Biological performance*
   - Unknown, biological evaluation to occur in 2007.
4) *Future plans*
   - Construct one TSW1 and one TSW2 by March 2007.

- Conduct direct injury and survival evaluation to investigate fish injury potential.
  - TSW1 vs. TSW2 vs. Conventional spillbay.
- Pending acceptable results from direct injury evaluation proceed with spring and summer biological performance evaluation with 2 TSWs in 2007.
- Pending 2007 TSW biological performance testing results.
  - Are we meeting our goal(s)?
    - Do the SFO(s) provide a survival benefit?
    - Are the SFO(s) effective at passing fish safely?
  - BiOp remand - project specific performance goals?
  - Develop TSW operational plan pending adequate performance in 2007.
  - Establish regional prioritization of other SFO alternatives identified during 2005 SFO workshop.
  - Proceed with further development of regionally prioritized SFO alternatives if warranted.

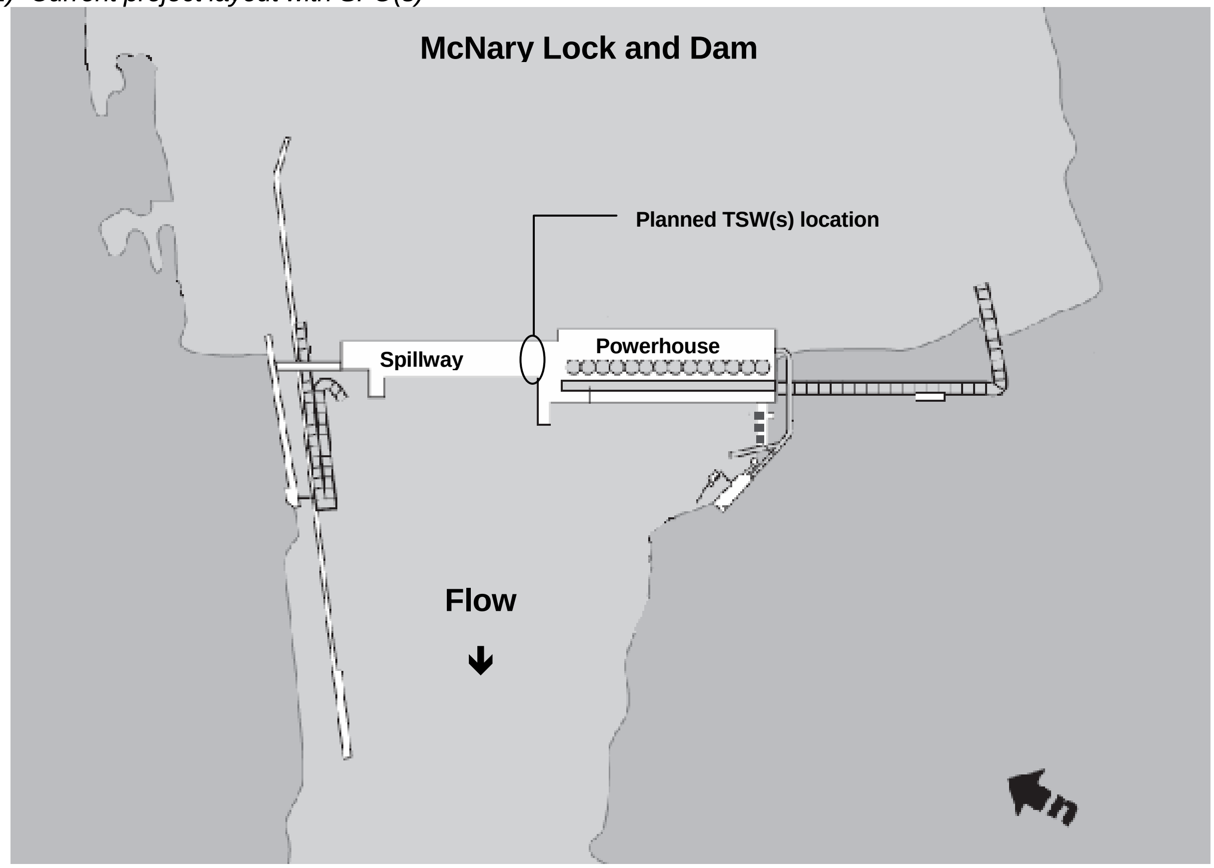
D) Conclusions and lessons learned (from all designs):

1) *Data gaps identified*
   - Forebay fish approach pattern and subsequent route of passage data to aid in the placement of SFOs.
2) *Guiding principles/recipes for success*
   - Locate SFOs either where fish congregate of have a high likelihood of discovery.
3) *Pit falls, i.e. what not to do*
   - Not sure yet since project is not yet complete.
4) *Absolute requirements*
   - Pass fish safely downstream and provide an overall survival benefit.
   - Not impact projects ability to pass large flood events that create a dam safety concern.
5) *If you had it to do all over again, what would you do differently?*
   - We'll let you know when the project is complete.

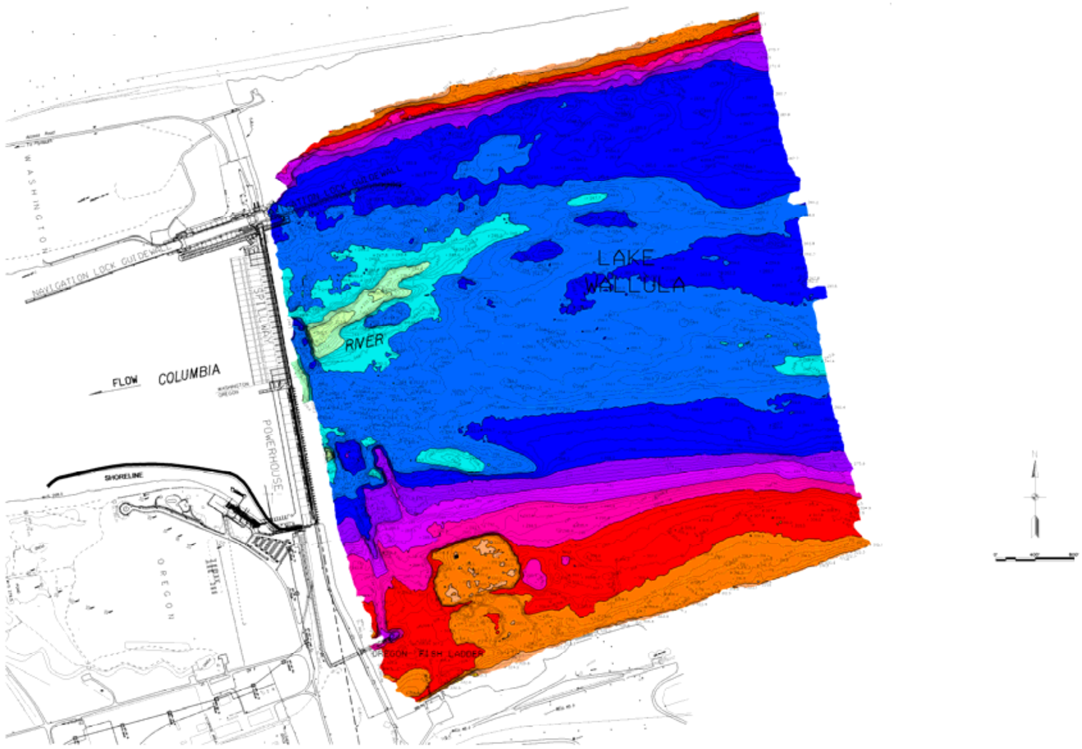
E) Exhibits:

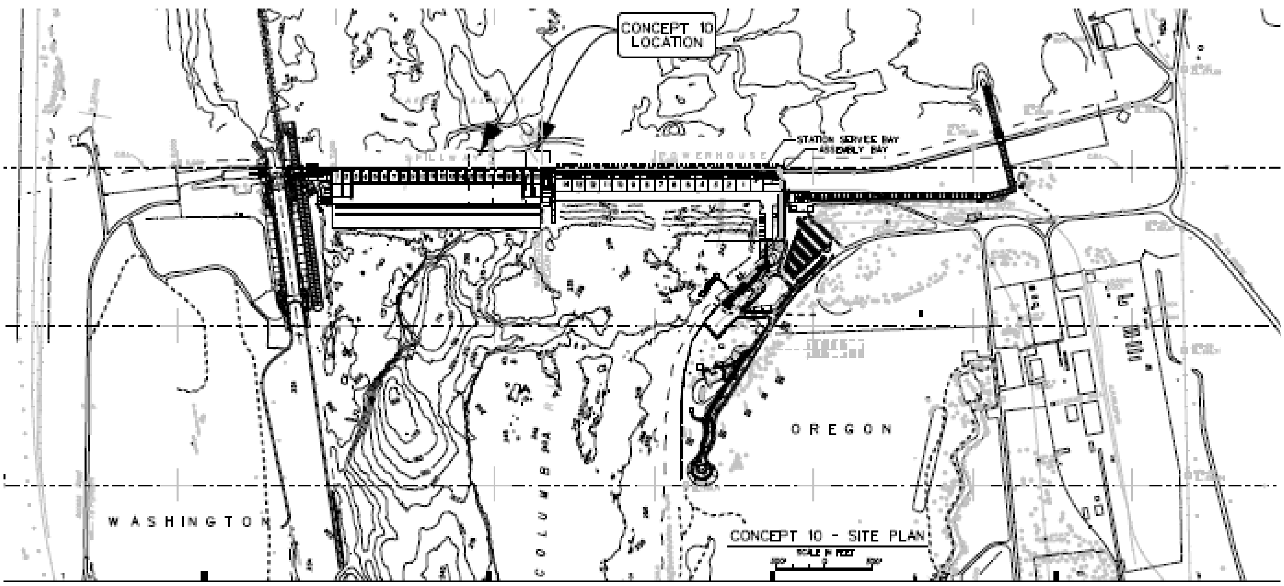
1) *Arial photo*

2) Current project layout with SFO(s)

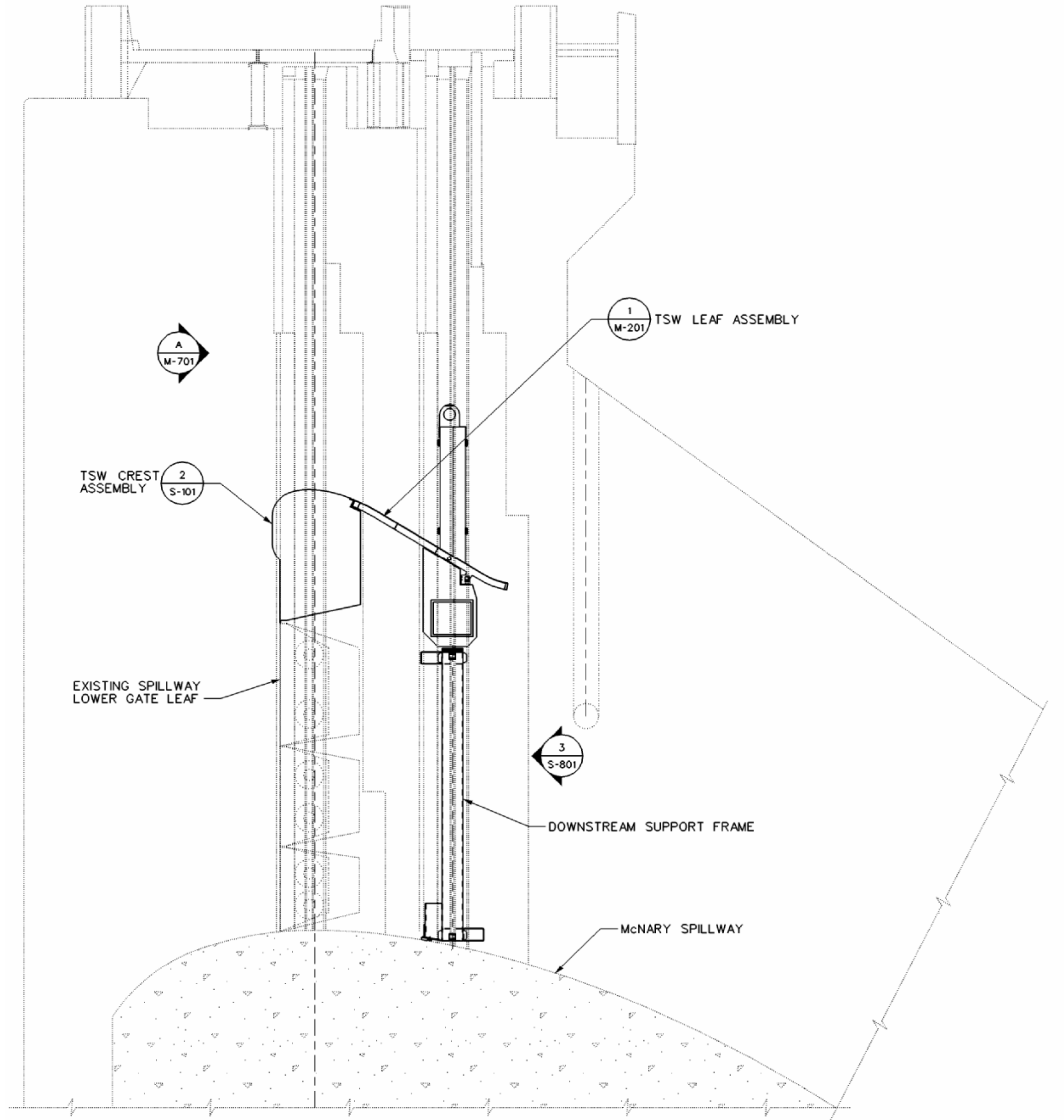


3) Forebay and tailrace bathymetry

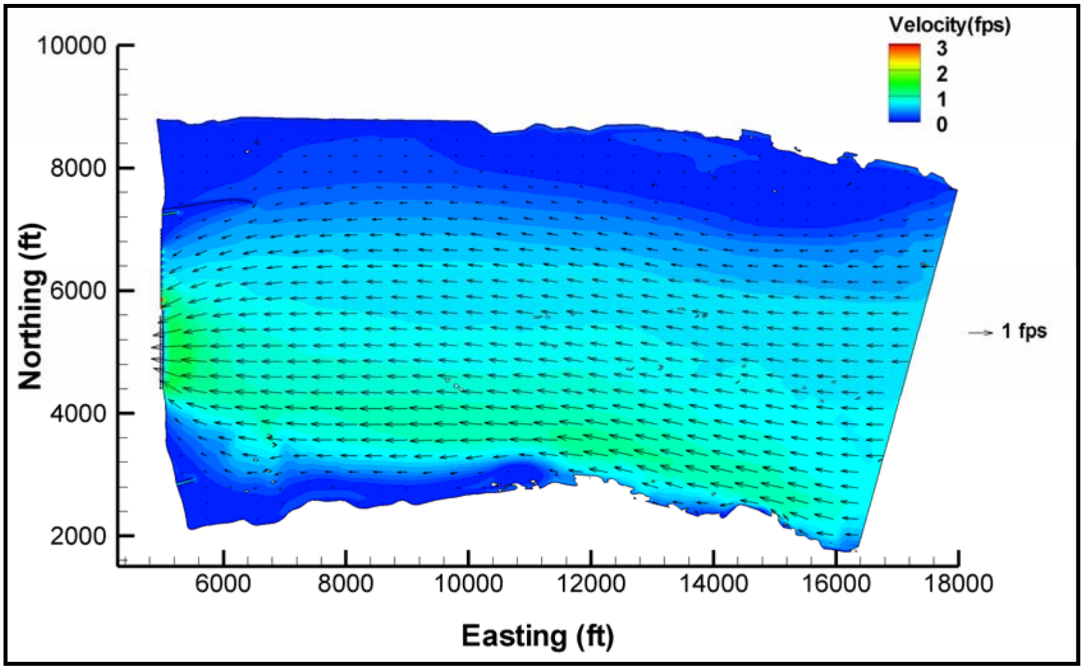


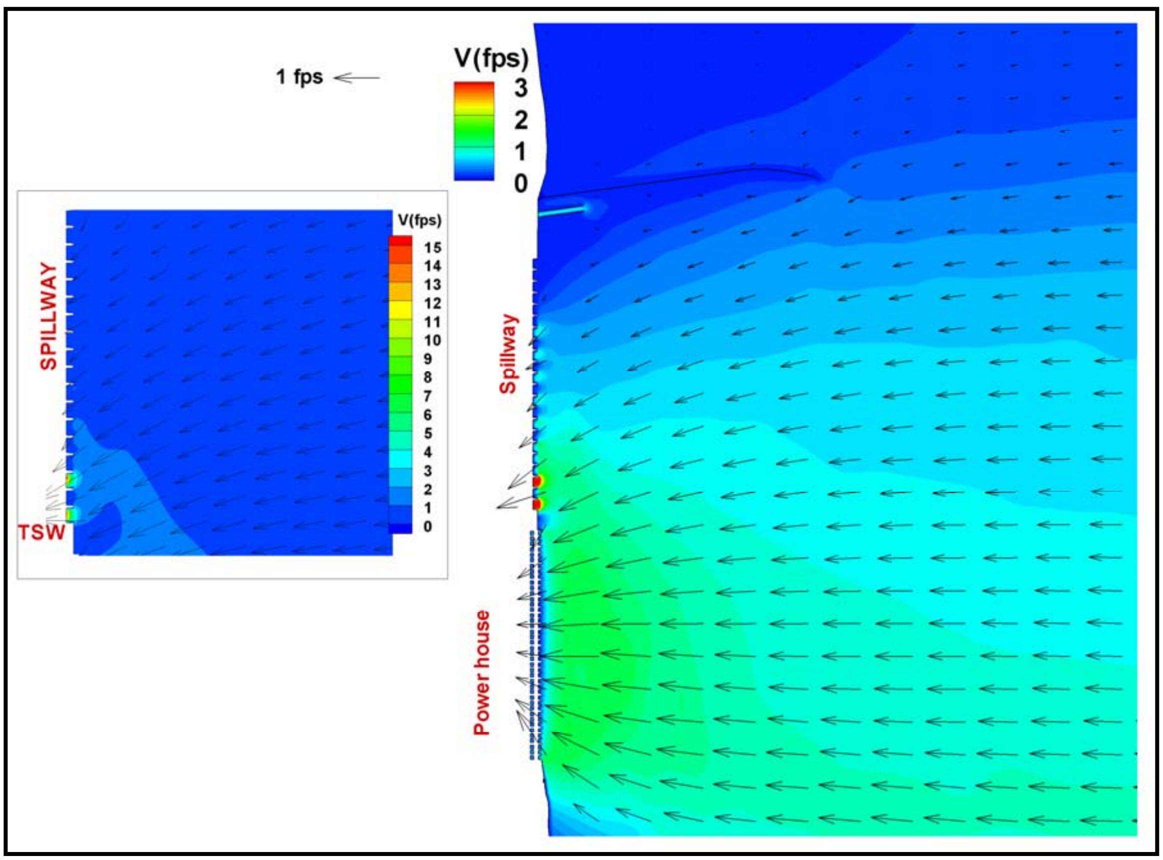


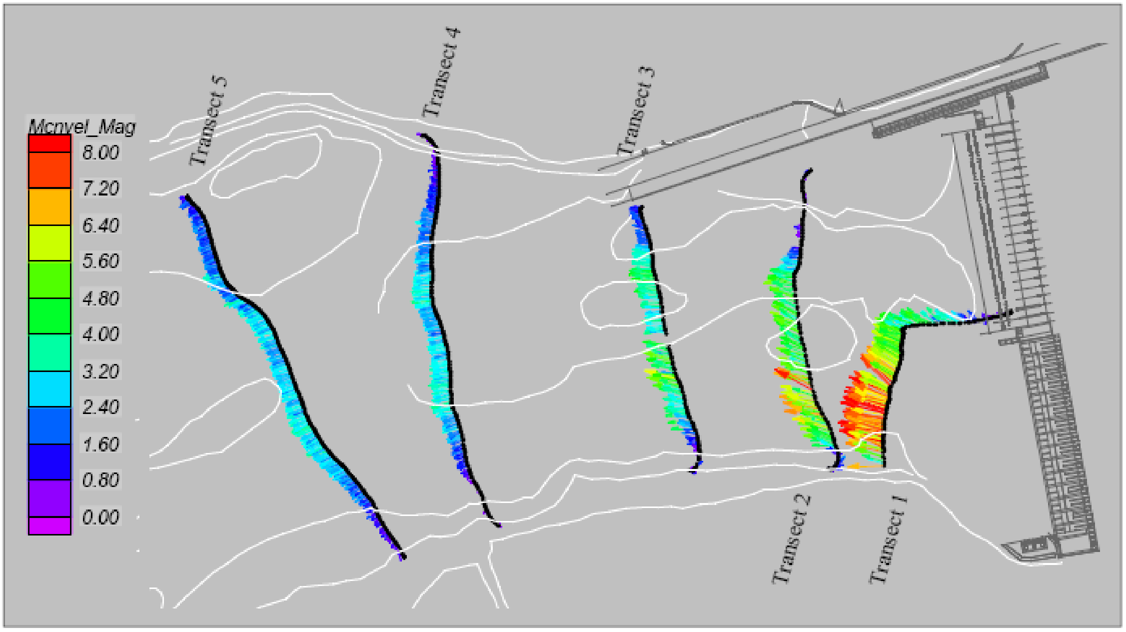
4) Current plan and profile of the SFO structure



5) *Forebay & tailrace flow fields* - Surface bypass structure (TSW) at spillway bays 22 and 20. Forebay WSEL 338.0 fmsl, river total flow 204.9 kcfs (PH=149.8 kcfs & SP=51.1 kcfs).







Depth-Averaged ADCP Velocities below McNary Dam, 1300 hrs April 2, 2000
(Q_{ph}=154 kcfs, Q_{sp}=0, TWE=265.8 ft)
(Data Aggregation by Ensemble Number with No Filter)

General Stats:

- Began operation in 1953.
- Located at Columbia River mile 292.
- Fourth dam upstream of river mouth.
- First dam below confluence of Columbia and Snake rivers.
- No existing SFOs.
- Powerhouse
  - Length – 1,422 ft.
  - Fourteen Kaplan turbine units.
  - Operating elevation range 335 – 340 ft msl.
  - ±1% peak efficiency operational range ~7.8 – 12.3 kcfs/unit (max. ~ 16.4 kcfs).
  - Powerhouse capacity ~172 kcfs (max. ~232 kcfs).
- Spillway
  - Length – 1,310 ft.
  - Twenty-two vertical-lift gate controlled spillbays.
  - Peak design discharge – 2,200 kcfs.
  - Crest elevation – 291.0 ft msl.
  - Spillway deflector elevation – 256.0 ft msl.
- Spring operation
  - Spill to the gas cap (~160-180 kcfs) from 1800-0600 hours, April 10 – late-June (BiOP).
  - Due to limited powerhouse capacity (~172 kcfs), Project is forced to spill periodically from 0600-1800 hours.
  - 2005 evaluation – BiOp vs. 24-hour, 85 kcfs spill.
  - 2006 evaluation – BiOp vs. 24-hour, 40% spill.
- Summer operations
  - No spill (BiOp)
  - 2005 court-ordered spill – 24-hour all in excess of 50 kcfs spill (~60%) from July 1 – August 31.
  - 2006 court-ordered spill – 24-hour 60% vs. 24-hour 40% spill from June 20 – August 31.

Passage and survival evaluation – June 20 – July 22.

ENSR | AECOM

Project Description

Project: John Day Surface Bypass

Presenter: ***Brad Eppard***

Completed By:__________________________

Email:_________________________________

Phone:________________________________

Date: updated 12/20/06, GEJ

A) Introduction:

1) *Why was SFO considered?*
   - 1995 biological opinion: goals for 80% FPE and 95% survival
2) *What initial data kick-started the process?*
   - 1995: feasibility study of conceptual alternatives
     - Volumes 1&2: surface bypass alternative study at John Day Powerhouse; Final report to USACE NWP, Harza and ENSR (1996)
     - USACE NWP feature design memorandum No. 52: John Day Lock and Dam Surface Bypass Spillway (Montgomery Watson 1998)
   - Alternatives considered:
     - Collection along powerhouse face
     - Modular channel collector
     - Floating surface collector
     - Guides to powerhouse spill
     - Surface collector at skeleton bays
   - When choosing the best alternative the following were considered
     - Biological factors: FPE, potential for fish injury in conveyance zone, potential for delays, potential to create predator habitat, and flexibility for bypass outfall locations
     - Hydraulic factors: zone of influence, maximum flow rate into SFO, maximum water velocity at SFO entrance
     - Cost: modification to existing structures, use of existing facilities, construction, O&M
     - Operations factors: constraints on powerhouse operation, debris handling and removal, available O&M personnel
3) *What SFOs were investigated (model or prototype)?*
   - Surface spill (prototype 1997)
   - Surface collector at the skeleton bays (engineering study)

B) SFO Alternative 1 (investigated and ultimately discarded): Surface Spill Weir

1) *History of development and testing with the decision path.*
   - In 1997, the Corps of Engineers installed stop logs in Spill Bays 18 and 19 to create prototype overflow weirs, i.e., surface spill SFOs. The weirs, however, allowed both overflow and underflow, so there were not true surface spill SFOs.Construct in Units 19 & 20.
   - BioSonics (1999) reported that, in spring, overall averages for efficiency and effectiveness at Bays 18 and 19 were significantly higher during the weir "out" conditions than the weir "in" condition (P=0.06 and P=0.07, respectively). In summer, passage efficiency and effectiveness were similar between weirs in and out. The study results were likely affected by high discharge levels.
2) *What modeling and prototype development was done?*
   - ENSR (1997) performed an hydraulic model study of the over/under spillway weir.
3) *Why was the SFO discarded as a design alternative?*
   - This was only a makeshift, prototype evaluation. The concept was not discarded.

C) SFO Alternative 2 (investigated and on hold): Surface Collectors at Skeleton Bays

1) *History of development and testing with the decision path.*
   - In 1997, the Corps of Engineers initiated engineering studies of the skeleton bays at the powerhouse to be converted to SFOs.

2) *What modeling and prototype development was done?*
   -
3) *Why was the SFO discarded as a design alternative?*
   - The concept has not been not discarded.

D) Present status of facility:

1) *Project layout/bypass system configuration:*
   - CH2M-Hill (2001) prepared a DDR for a removable spillway weir at John Day Dam.
2) *Cost (Design, Construction, Evaluation)*
   - Not currently available
3) *Biological performance*
   - Not currently available
4) *Future plans*
   - Complete an alternatives feasibility study:
     - Tailrace improvements: there are areas with stagnant flow in tailrace that must be avoided
     - Surface flow outlet structure

E) Exhibits:

1) *Aerial photo*

2) *Current project layout with SFO* (not available at this time)
3) *Forebay and tailrace bathymetry* (not available at this time)
4) *Current plan and profile of the SFO structure* (not available at this time)
5) *Forebay & tailrace flow fields* (not available at this time)

General Stats:

- 20 Spillbays (18 w/deflectors)
- Capacity =2.3 million cfs
- 20 Turbine bays
- 16 Kaplan 6-blade turbines
- 4 “Skeleton bays”
- Capacity= 3.2 million CFS (2,160 MW)
- Juvenile bypass system
    - Standard traveling screens
    - Smolt monitoring
- Adult fishways

Project Description

Project: The Dalles Dam

Presenter: ***Laurie Ebner***

Completed By: Laurie Ebner

Email: Laurie.L.Ebner@nwp01.usace.army.mil

Phone: 503-808-4880

Date: updated 12/20/06 (revised by GEJ 1/4/07 and 1/9/07)

A) Introduction:

1) *Why was SFO considered?*
   - ESA as reflected in Biological Opinions from the National Marine Fisheries Service on operation of the Federal Columbia River Power System.
2) *What initial data kick-started the process?*
   - Harza and ENSR (1996) and Harza et al. (1995) reports
     - Surface Collection with Full Flow Bypass
     - Venturi Sluiceway Collector
     - VBS Sluiceway Collector
   - The Dalles Ice and Trash Sluiceway passed a large number of juveniles with high survival. Approximately 40-55% of the smolts pass TDA via the sluiceway, during periods when no spill is occurring (Giorgi and Stevenson 1995).
   - Furthermore, the sluiceway is particularly effective since less than 2% of the total river flow is discharged through that passage route.
3) *What SFOs were investigated (model or prototype)?*
   - Sluiceway with reconfigured entrances and turbine intake occlusion (1995 and 1996))
   - Spillway baffles (1995 and 1996)
   - Turbine intake occlusion with J-blocks (2000-2002)
   - Forebay behavioral guidance structure (engineering in 2005-2006)
   - Sluiceway at the powerhouse (1978 to present)
     - Outfall Relocation
     - Entrance Improvements

B) **SFO Alternative 1 (investigated and ultimately discarded): Reconfigured Sluiceway Entrances (1995)**

1) *History of development and testing with the decision path.*
   - In 1995 the Corps implemented two SFO strategies at The Dalles to enhance performance of the ice-trash sluiceway:
     - First, trash racks were blocked from about elevation 155 to 120 ft MSL at two turbine intakes below open sluice gates at MU 1.
     - Second, a "surface skimmer" was retrofit on the dam, replacing in the upper two trash racks below twp sluice gates. The back of this steel box served as a trash rack blockage. The front had a vertical slot entrance (dimensions not apparent in the report). Flow into the skimmer was controlled by the sluice gates.
   - The objective of blocking the trash racks was to enhance the zone of separation by altering current patterns at the face of the dam to drive the turbine flownet deeper, away from surface-oriented smolts, and deepen the influence of the flownet from the surface entrance of the sluiceway, thereby attracting more smolts.
   - The objective of the surface skimmer was to mimic the vertical slot entrance in place at Wells Dam, in terms of dimensions and entrance velocity. It was essentially a box that extended downward blocking the upper two trashracks, with a vertical slot entrance. It emptied into the sluiceway.
   - No significant differences in sluiceway efficiency (defined here as sluice passage divided sluice plus turbine passage for turbines below the open gates) were found between blocked and unblocked trash racks (Nagy and Shutters 1995). Researchers noted that this comparison was likely affected by differing acoustic detection probabilities between the different treatments because of differing

velocity fields. Sluice efficiency for the skimmer at 1-2 (daily mean 53%) was lower than at the unmodified sluice entrance 2-2 (daily mean 77%).
- In 1996, the trashrack blockage was expanded (bottom of blockage at elev. 100 ft).
- SFO research was put on hold at The Dalles in 1997 to focus SFO development resources on Bonneville and John Day dams.

2) *What modeling and prototype development was done?*
- No modeling was done *before* the construction and installation of the reconfigured sluiceway entrance structures because this effort was fast-tracked to installation as part of the Corps' Surface Bypass Program, which was initiated one year earlier in 1994.
- Hydraulic data were collected in a physical scale model (1:25) during summer 1995.
- Goodell (1996) reported ADCP data collected in 1995 with the transducers deployed from a crane to sample velocities about 14-21 m from the surface skim at Sluicegate 1-2. Data were apparently good down to about 7 m; deeper than that it appeared the data were biased by one or more of the acoustic beams hitting the dam. The effect of the surface skim vertical slot at Sluicegate 1-2 could not be discerned 14 m away.
- ENSR (1997) reported ADCP data collected in 1996 upstream of the trashrack blockages.

3) *Why was the SFO discarded as a design alternative?*
- A key result from SFO research at The Dalles Dam in 1995 was that it appeared an unmodified sluice entrance had apparently higher passage rates and bypass efficiencies than the sluice gate with a reconfigured vertical slot entrance. The SFO strategy of blocking trashracks and installing reconfigured sluiceway entrances did not apparently enhance sluiceway performance as they were designed to.

C) **SFO Alternative 2 (investigated and ultimately discarded): Spill Bay Baffles (1995-1996)**

1) *History of development and testing with the decision path.*
- At The Dalles in 1995, the Corps tested low volume spillway baffles (vertical slot) and an overflow weir (top spill). At the spillway, two bays were retrofitted with vertical slot entrance structures upstream of the tainter gate. Each vertical slot was 16 ft wide and extended from the spill ogee to the surface. The top spill weir was 20 ft deep at Bay 6.
- Tests of the low volume spill baffles at The Dalles were inconclusive because of the high volume of spill at The Dalles in 1995 and 1996. The low volume spill at the test spill bays (3.2 kcfs) was dwarfed by the large amount of spill elsewhere (14.5 kcfs in adjacent bays). In addition, spill through the test bays was limited by structural constraints of the baffles.
- Researchers did not report fish passage data from the spill bay baffle tests, because the study was compromised by large flow differences between test (3.2 kcfs) and control (14.5 kcfs) bays (Nagy and Shutters 1995).

2) *What modeling and prototype development was done?*
- Goodell (1996) reported ADCP data collected in 1995 with the transducers deployed from a crane to sample velocities upstream of the vertical slot at Bay 12 and the surface weir in Bay 6. Velocities for gate openings of 1, 2, and 3 ft were sampled.
- CEWES (1996) reported velocity measurements from a 1:40 scale physical model of a six-bay spillway section for TDA. Two types of spill bay bulkhead configurations were examined: I-slot and surface spill weir.

3) *Why was the SFO discarded as a design alternative?*
- The spill bay baffle concept at TDA was shelved when other dams replaced TDA as a priority for SFO development in 1997.

D) **SFO Alternative 3 (investigated and ultimately discarded): Turbine Intake Occlusion with J-Blocks (2000-2002)**

1) *History of development and testing with the decision path.*
- Objective to Improve Juvenile Fish Passage Survival by:
  - Reducing turbine entrainment of juvenile fish into turbines
  - Increasing sluiceway efficiency
  - Increasing spillway efficiency

- Model testing in a 1:25 sectional model: Hydraulic criteria to change characteristics of the flow entering the turbine
- Prototype testing at both Fish Units and Main Units 1-5
  - Vertical Occlusions tested in the late 1990s
  - J-Blocks tested in early 2000s
  - Results did not show a decrease in turbine passed fish
- CFD modeling (ENSR and CENWP)
- DDR and Plans and Specs Developed: Estimated Construction Cost of $70 million

2) *What modeling and prototype development was done?*
   - Vertical Occlusions were modeled in a 1:25 sectional model in the 1990s. Prototype tested and biological results showed no reduction in turbine entrainment. J-Blocks were then modeled in the 1:25 sectional model and in CFD. Prototype testing was conducted in 2002 and results showed no reduction in turbine entrainment.

3) *Why was the SFO discarded as a design alternative?*
   - Biological results showed that turbine entrainment did not decrease with the devices in place (Johnson et al. 2003).

E) **SFO Alternative 4 (investigated and ultimately discarded): Forebay Behavioral Guidance Structure**

1) *History of development and testing with the decision path.*
   - Objective to improve Juvenile Fish Dam Survival by reducing turbine entrained fish and increasing spillway passed fish, and accomplish this at reduce spill levels (less than current 40%)
   - The recommended design is a tethered concept where the floating wall is anchored to the river bottom. The alignment for the BGS was at an oblique angle to the powerhouse starting in the vicinity upstream of the adult fishway exit at the east end of the powerhouse and extending across the forebay.
   - The estimated cost was about $55M. .
   - A Decision Documentation Report was completed (USACE 2006).

2) *What modeling and prototype development was done?*
   - The 1:80 General Physical Model and a CFD model of the forebay were used to select an alignment and draft. The modeling effort was started in 2004.
   - Physical and CFD modeling showed that maximum length was about 1000 ft.

3) *Why was the SFO discarded as a design alternative?*
   - The Corps concluded (USACE 2006) that before the BGS can move forward to Plans and Specifications that a new site selection study will needed to address fish passage objectives and navigation concerns, assuming regional concurrence that a BGS at The Dalles Dam is justified.

F) SFO Alternative 5: Sluiceway at the Powerhouse (1978 to present)

1) *History of development and testing with the decision path*.
   - The sluiceway at The Dalles Dam is a functional surface flow outlet[1] that has been operated to pass juvenile salmonids for over 35 years. Initial research established that downstream migrants used the sluiceway and led to a recommendation for "full-time operation of the ice-trash sluiceway at The Dalles Dam with maximum flow" (Michimoto 1971). Sluiceway operations were established from data collected in the late 1970s and early 1980s (Nichols 1979 and 1980; Nichols and Ransom 1981 and 1982).
   - In 2004 and 2005, the Corps maximized flow through the sluiceway and did research to identify sluiceway entrances to open, seasonal differences, and operating turbines (e.g., Johnson et al. 2005; 2006).
   - Water enters the sluiceway channel from the forebay when gates are moved off the sill at elevation 151 ft. A maximum of six sluice gates can be opened at any time before reaching the hydraulic

[1] A surface flow outlet at a hydropower dam is any portal where water flows from the forebay over the dam structure to the river downstream of the dam.

capacity of the channel (~4,500 cfs). Flow into the sluiceway is dependent on forebay elevation and the number and location of open gates.

- Sluiceway entrance improvements are being planned.
- Outfall relocation (on hold). A Decision Documentation Report was completed (USACE 2001).
  - Objective to increase survival of juvenile fish using the sluiceway
  - What cfs for the outfall flow (increased capacity, existing capacity, de-watered)
  - What spillway percentage
  - Physical modeling
    - 1:80 General Model (ERDC)
    - Sectional Model (NHC)
    - Alternative evaluation very dependent on spillway operations and modeling effort was put on hold until spillway improvements initiated

2) *What modeling and prototype development was done?*

- CFD model data show that flow approaches a sluice entrance at an oblique angle relative to the powerhouse, becoming more perpendicular to the dam the closer it gets. In cross-section, flow is horizontal (parallel to the surface) until it was near the dam where it went up to the sluice or down to the turbine intake. Flow into the sluiceway has a gradual acceleration until it was over the sill, then water accelerates rapidly into the sluice channel.
- CFD modeling revealed that nearfield forebay velocities are generally less than 2 feet per second (fps), except near sluiceway entrances.
- Sluiceway Outfall Relocation was conducted using a sectional model and the 1:80 general model. The work was conducted in 2003. Modeling was put on hold until spillway improvements were finalized since the egress conditions for the outfall relocation are dependent upon spill patterns.

G) Present status of facility (sluiceway):

1) *Project layout/bypass system configuration:*

- Ice and Trash Sluiceway an effective means to bypass migrating juveniles and kelts
- Operates 24-7 during passage season

2) *Cost (Design, Construction, Evaluation)*

- Cost currently being developed

3) *Biological performance*

- See following table (data are from Ploskey et al. 2001a (1999 study), Moursund et al. 2001, Moursund et al. 2002, Johnson et al. 2003, Johnson et al. 2005, Hausman et al. 2004; Counihan et al. 2006a, Hansel et al. 2004, Hansel et al. 2005; Counihan et al. 2006b, Cash et al. 2005, Beeman et al. 2006).

Species	Study-Year	Fish Collection Efficiency	Fish Collection Effectiveness
Run-at-Large Spring	1999	0.13	8.6
	2000	0.06	3.2
	2001	0.18	6.0
	2002	0.25	13.0
	2004	0.07	3.3
	Mean	0.14	6.8
Run-at-Large Summer	1999	0.12	8.6
	2000	0.07	3.3
	2001	0.05	1.4
	2002	0.11	7.6
	2004	0.04	1.7
	Mean	0.08	4.5
Chinook 0	2002	0.08	5.7
	2003	0.12	nd

Species	Study-Year	Fish Collection Efficiency	Fish Collection Effectiveness
	2004	0.07	2.8
	2004	0.01	0.4
	2005	0.04	1.1
	mean	0.06	2.5
Chinook 1	2002	0.10	6.7
	2003	0.17	nd
	2004	0.07	4.0
	2004	0.08	3.6
	2005	0.11	3.4
	mean	0.11	4.4
Steelhead	2002	0.14	9.3
	2003	nd	nd
	2004	nd	nd
	2004	0.05	2.4
	2005	nd	nd
	mean	0.10	5.9

4) *Future plans*
   - Sluiceway entrance improvements: objective to increase number of juvenile fish using the sluiceway and possibly:
     - Automated gates
     - Modified entrance
     - Reshape weir
     - Fish horns

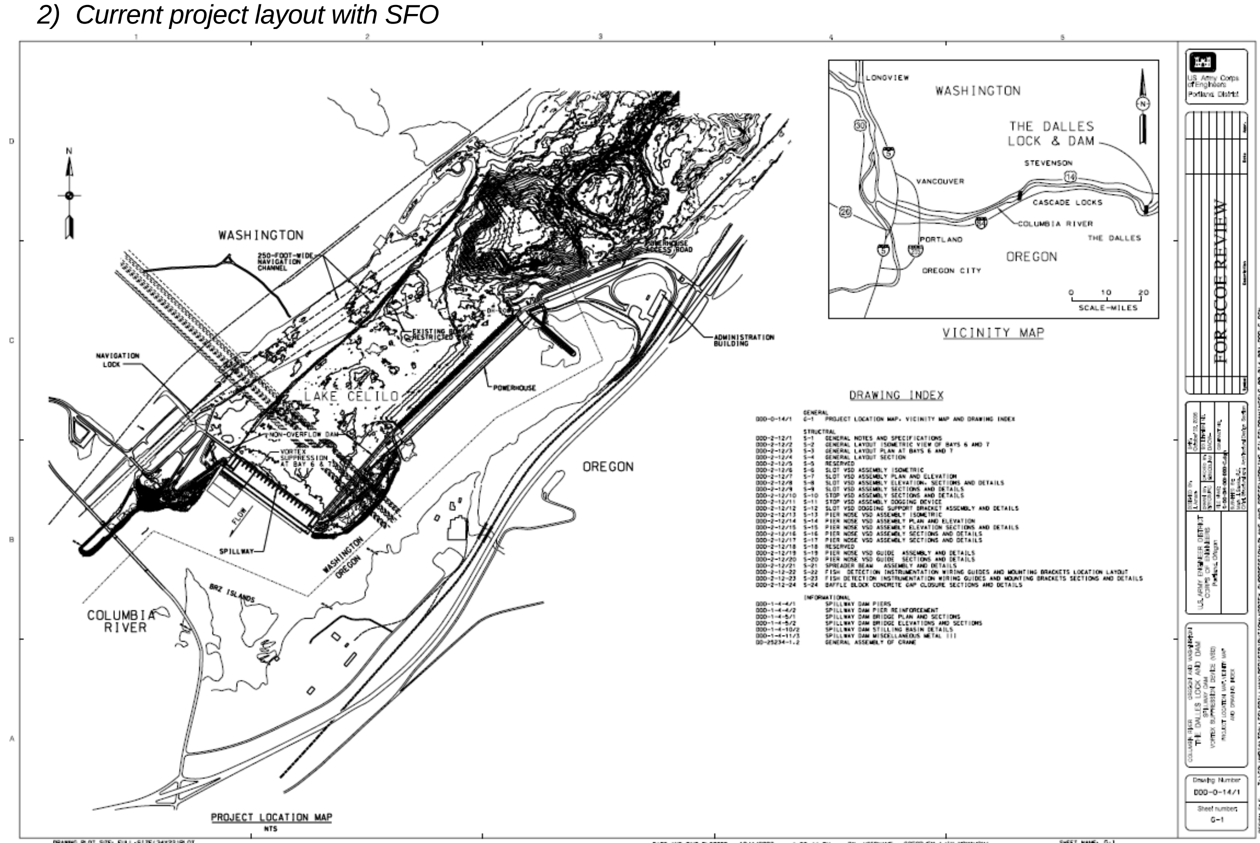
H) Conclusions and lessons learned (from all designs):

1) *Data gaps identified*
   - Fish approach information and sensitivity of hydraulic information to changes in operations.
2) *Guiding principles/recipes for success*
   - J-Blocks
     - Hydraulic criteria insufficient to achieve desired biological results
     - Flow characteristics as you approach the project and as you move through the forebay critical to juvenile fish distribution
     - The need for 3-D behavior in the forebay
   - Consider all authorized uses of the project during initial design phase
3) *Pit falls, i.e. what not to do*
   - Ignore project operations as a key variable in evaluating prototypes. Don't forget all of the project requirements during the design of fish facilities.
4) *Absolute requirements*
   - All of the hydraulic modeling needs to be completed before too much of the design effort
5) *If you had it to do all over again, what would you do differently?*
   - Collect fish approach information as soon as possible.

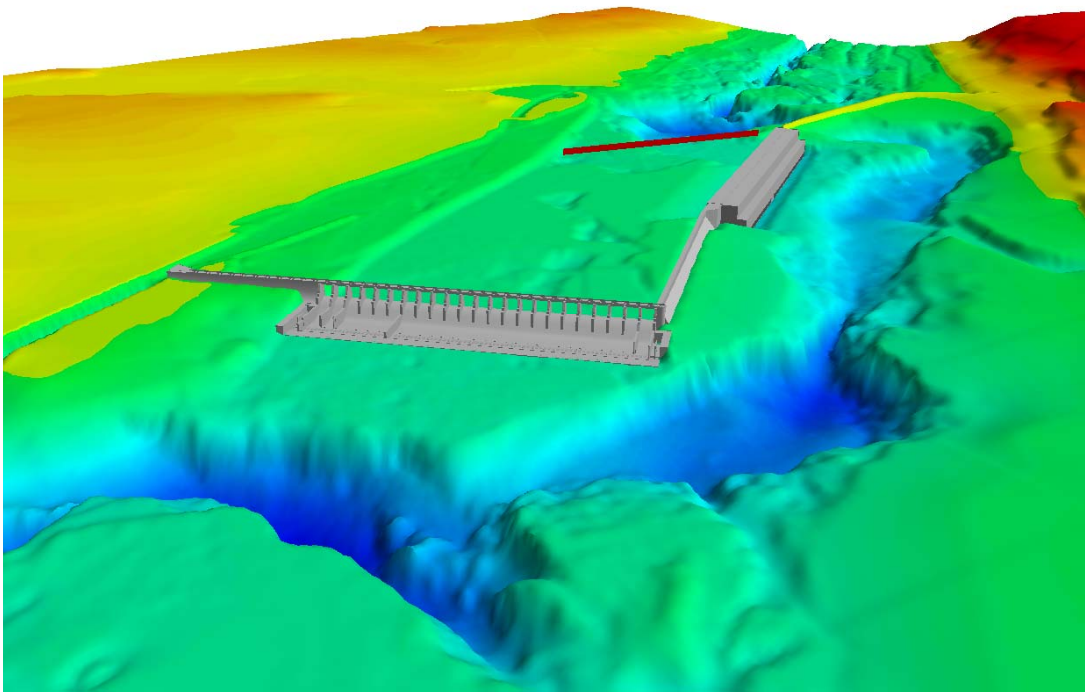
I) Exhibits:

1) Aerial photo

2) Current project layout with SFO

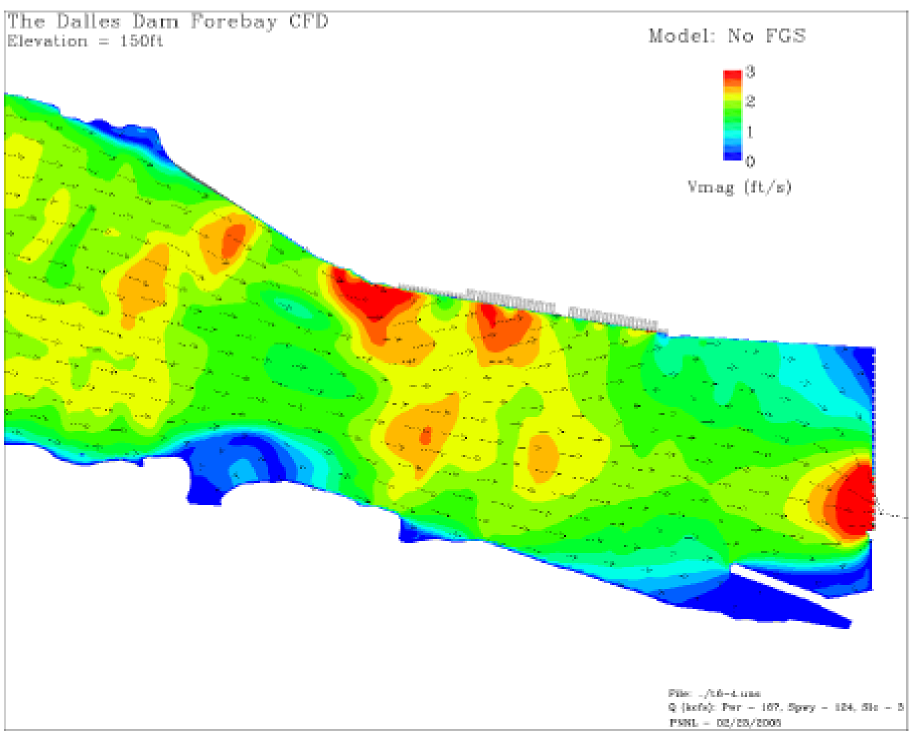


3) Forebay and tailrace bathymetry



4) Current plan and profile of the SFO structure (not available at this time)

5) *Forebay & tailrace flow fields*



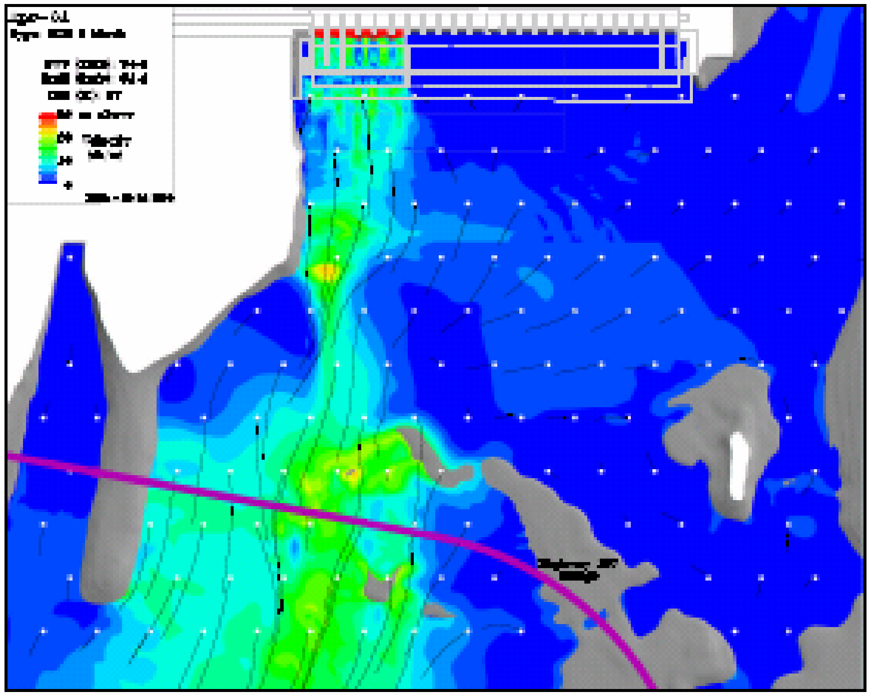
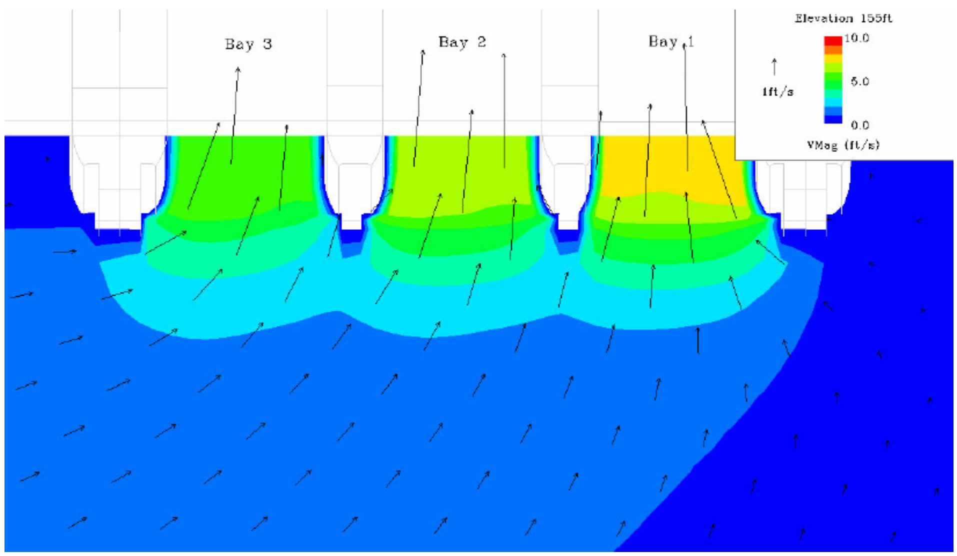
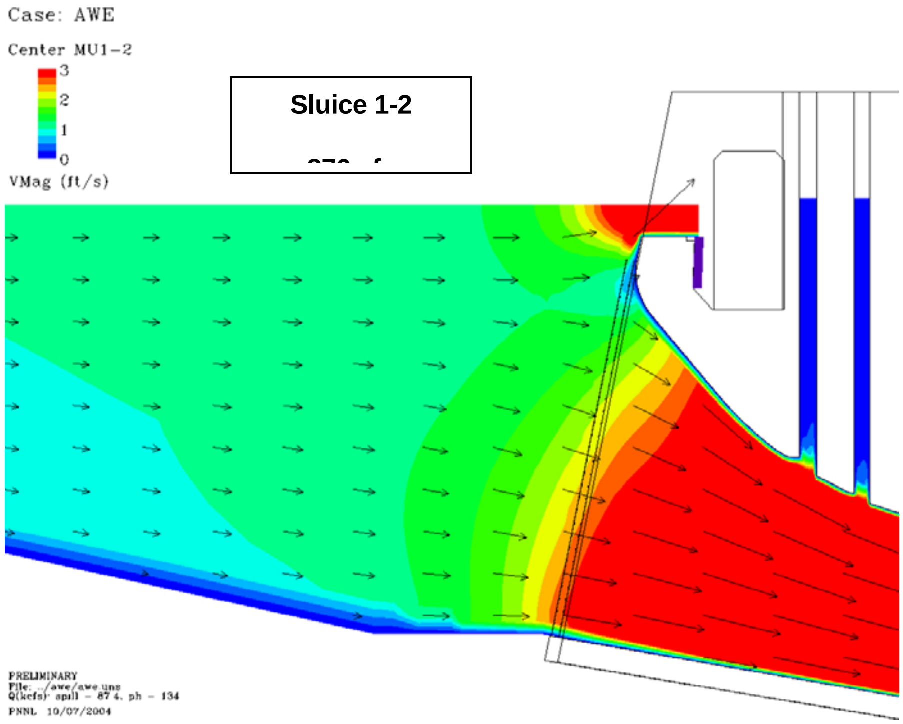
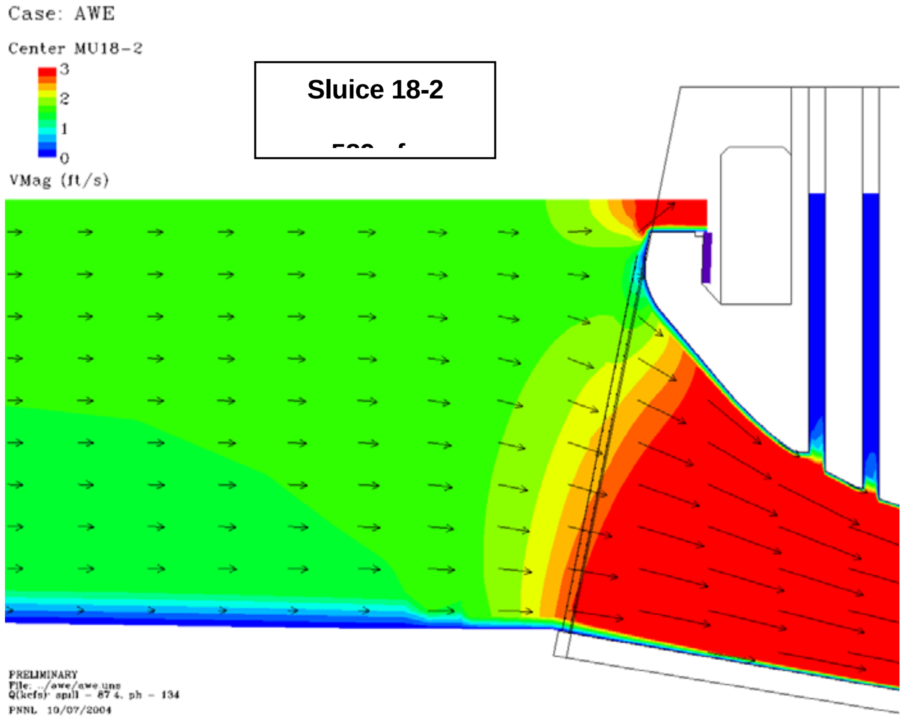


Figure H.1: Results for CFD model of The Dalles Dam tailrace (FullSpillwayA.pt-04.epx).



Plan view of water velocity at Elevation 155 ft at Sluice 2. Data are for a 6-gate configuration (SL 2 and 19). Total sluice flow was 4,580 cfs with total project discharge 207,580 cfs and 40% spill. The data are from CFD model runs provided by PNNL Hydrology Group.





Cross-sectional view of water velocity at two sluice entrances, 1-2 (top) and 18-2 (bottom) for the 6-gate configuration. The data are from CFD model runs provided by PNNL Hydrology Group.

General Stats:

- Powerhouse at right angle to the river
- Extreme bathymetry
- Powerhouse comprised of 22 main turbine units, two fish units and two station service units.
- The spillway comprised of 23 x 50-foot wide spillbays controlled by Tainter gates. The spillbays are separated by 10-foot piers.
- Juvenile Fish Passage
  - Spillway primary route (80% of fish at 40% spill) – survival (89% - 93%)
  - Ice and Trash Sluiceway (10% of fish at 40% spill – survival (93%-99%)
  - Turbines (10% of fish at 40% spill – survival (80%-84%)

Project Description

Project: Bonneville First Powerhouse

Presenters: ***Blaine Ebberts and Karen Kuhn***

Completed By: Blaine Ebberts, Karen Kuhn, Gary Johnson

Email: Blaine.D.Ebberts@nwp01.usace.army.mil

Phone: 503-808-4763

Date:________________________________

A) Introduction:

1) Why was SFO considered?

- The Biological Opinions on operation of the Federal Columbia River Power System (NMFS 1995, 1998; 2000; 2004), mandated development of surface bypasses at Bonneville Dam, because fish guidance efficiency (FGE) and smolt survival associated with turbine intake screens was substandard (e.g., Dawley et al. 1992; Gilbreath et al. 1993; Monk et al. 1999).
- In the mid-1990s the Corps instituted a formal Surface Flow Bypass Program whose goal was to "…develop and evaluate surface bypass and collection prototype concepts that will lead, if justified by prototype test results, to permanent systems for improving survival of juvenile salmon…" (USACE 1995).
- The Independent Scientific Advisory Board reviewed and supported this initiative (Bisson et al. 1999).

2) What initial data kick-started the process?

- The B1 Sluiceway was known to pass juvenile salmonids. It has been in use for this purpose since the late 1960s. (See description below)
- Possible SFO alternatives determined in the 1996 Surface Bypass Alternatives Study
  - Alternative A: Collection along PH face
  - Alt. B: High flow corner collector at south end of PH
  - Alt. C: Bypass channel attached to intakes with extended bar screens

3) What SFOs were investigated (model or prototype)?

- B1 Sluiceway
- Alternative A: Collection along PH face as represented by the Prototype Surface Collector (PSC)

B) SFO Alternative 1: B1 Sluiceway

1) History of development and testing with the decision path.

- For over 30 years, the Bonneville Dam First Powerhouse (B1) sluiceway has been operated as a non-turbine passage route for juvenile salmonids.
- The ice-trash sluiceway extends along the surface of the forebay side of the B1 powerhouse. There is a leaf gate above each turbine intake.
- Flow through sluice gates is strongly influenced by forebay elevation. Maximum total capacity of the sluiceway is about 2,000 cfs (1,500 cfs if non-submergence and channel velocity criteria are to be met). A gate at the south end of the sluiceway controls sluiceway channel flow. At this point, flow plunges into a raceway, which turns downstream and discharges into the tailrace at the south end of the B1 powerhouse.
- In the 1960s and 1970s, sluiceway research demonstrated that surface routes would pass appreciable numbers of smolts at B1. However, fisheries managers felt the sluiceway system was inadequate as a stand-alone system because sluiceway flow was limited to about 2,100 cfs, and conveyance and outfall conditions were poor.

2) What modeling and prototype development was done?

- Physical hydraulic modeling (1 and 3 dimensional velocities in front of the sluiceways) on 1:40 scale hydraulic model for various potential conditions for the Trashrack Blockage Study, 1997.
- Field hydraulic data (1 dimensional velocities in front of the sluiceways) for Blocked Trashrack Study, 1996.
- Numerical hydraulic models and CFD models have been used to emulate the flow conditions into the sluiceway entrances and conveyance channel to determine optimum operation during fish passage season (1997-2006).

- Trashrack Blockage Study (1996)
  - In 1996 at B1, trashracks at Units 3 and 5 were blocked to El. 33 ft (about 41 ft deep) as an inexpensive, preliminary surface bypass test. The purpose of the blockages was to occlude part of the intake entrance area to intensify and deepen the "zone of separation" between the turbine flow and surface sluiceway flow. The intent was to determine if surface-oriented smolts would exhibit an enhanced proclivity to resist sounding if a large zone of separation could be established.
  - While the experiment with trashrack blockages at B1 in 1996 did not reveal negative impacts from the blockages, the results were not encouraging.
- *Total Project Passage Studies (1999-2005) – B1 Sluiceway Efficiency*
  - Efficiency and effectiveness at the B1 Sluiceway, relative to the B1 powerhouse, were estimated as part of the total project passage studies designed to estimate fish passage efficiency for Bonneville Dam as a whole during 2000-2005. Recall, 2001 was a drought year, so the B1 turbines were operated sparingly during the downstream migration period. No passage studies were conducted in 2003. Except for 2000, B2 was the priority powerhouse for power production.
  - Approximately 1/3 of the yearling and subyearling Chinook salmon passing B1 used the sluiceway during studies in 2000-2005; for steelhead, about ½ used the sluiceway and ½ used the B1 turbines (Table 1). For the run-at-large during spring and summer, sluiceway efficiencies were also about 1/3 of total B1 passage (Table 1). Effectiveness estimates for the B1 sluiceway ranged from 9 to 34 (Table 1).

3) Conclusion
- The B1 sluiceway continues to be a valued passage route for juvenile salmonids at Bonneville Dam. It could provide the basis to develop a more extensive surface flow outlet at B1.

Table 1. B1 sluice efficiency and effectiveness from radio telemetry and hydroacoustic studies at Bonneville Dam during 1999-2005.

Species	Study-Year	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
Chinook 0	2000	0.68	nd	nd		nd	Evans et al. 2006 (table 18, p.29)
	2001	0.70	nd	nd		nd	Evans et al. 2006 (table 18
	2002	0.48	28.0	nd		nd	Evans et al. 2006 (table 18
	2004	0.47	3.7	nd		nd	Evans et al. 2006 (table 18
	2005			nd		nd	
	mean	0.58	15.9				
Chinook 1	2000	0.29	nd	nd		nd	Regan et al. 2006 (table 18, p.33)
	2001	0.77	nd	nd		nd	Regan et al. 2006 (table 18
	2002	0.35	18.6	nd		nd	Regan et al. 2006 (table 18
	2004	0.53	14.6		0.919		Regan et al. 2006 (table 18
	2005				0.937		Counihan et al. 2006b
	mean	0.49	16.6		0.928		
Steelhead	2000	0.44	nd	nd		nd	Regan et al. 2006 (table 18
	2001	nd	nd	nd		nd	Regan et al. 2006 (table 18
	2002	0.65	34.1				Regan et al. 2006 (table 18
	2004	0.55	15.1		0.985		Regan et al. 2006 (table 18
	2005				0.933		Counihan et al. 2005b
	mean	0.55	24.6		0.959		
Run-at-Large Spring	2002	0.33	14.0	nd	nd	nd	Ploskey et al. 2003
	2004	0.33	7.6	nd	nd	nd	Ploskey et al. 2005
	2005	0.37	7.6	nd	nd	nd	Ploskey et al. 2006 (table 3.1, p.3.17)
	mean	0.34	9.7	nd	nd	nd	

Species	Study-Year	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate	Total Survival Rate	Injury Rate	Data Sources
Run-at-Large Summer	2002	0.29	2.7	nd	nd	nd	Ploskey et al. 2003
	2004	0.38	9.3	nd	nd	nd	Ploskey et al. 2005
	2005	0.71	4.3	nd	nd	nd	Ploskey et al. 2006 (table 3.1, p.3.17)
	mean	0.46	5.4				

[A] B1 Sluiceway discharge data not available to make the sluiceway effectiveness estimate.

C) SFO Alternative 2: Prototype Surface Collector (PSC)

1) History of development and testing with the decision path.

- The Corps of Engineers' Surface Bypass Program in 1995 started with development of alternatives for SFOs at B1 (Harza and ENSR 1996a). The alternatives included a full powerhouse collection structure (called Alternative A), a high flow corner collector at the south end of the powerhouse, and a bypass channel attached to intakes with extended bar screens.
- To test the SFO entrance concept for Alternative A, a prototype surface collector (PSC, Figure 1) was retrofitted to the upstream face of B1 at Units 3-6 in 1998.
- The purpose of the PSC was to provide a field site to investigate hydraulic and biological performance for a potential surface bypass at B1. Fish entering the PSC passed through the structure into the turbine intake behind the PSC (Figure 2). The PSC was not designed to actually bypass fish around turbines. The intent was to use the PSC to examine entrance hydraulics and to examine the efficacy of surface bypass at B1 before building a large-scale prototype or full production surface bypass facilities at B1.
- An extensive biological evaluation was undertaken in 1998. In 1999, limited research occurred to prepare for culminating tests in 2000.

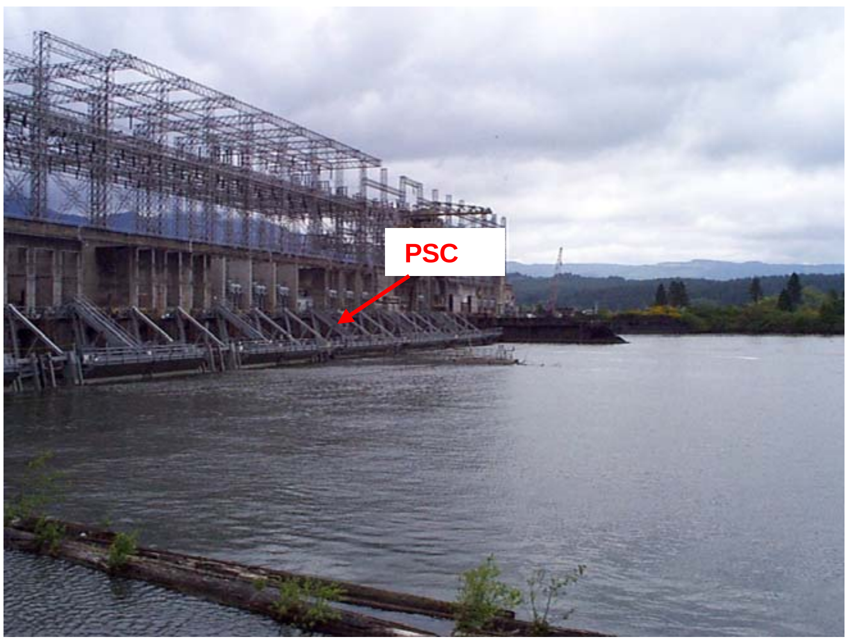


Figure 1. The prototype surface collector at B1. (Photograph courtesy of G. Ploskey)

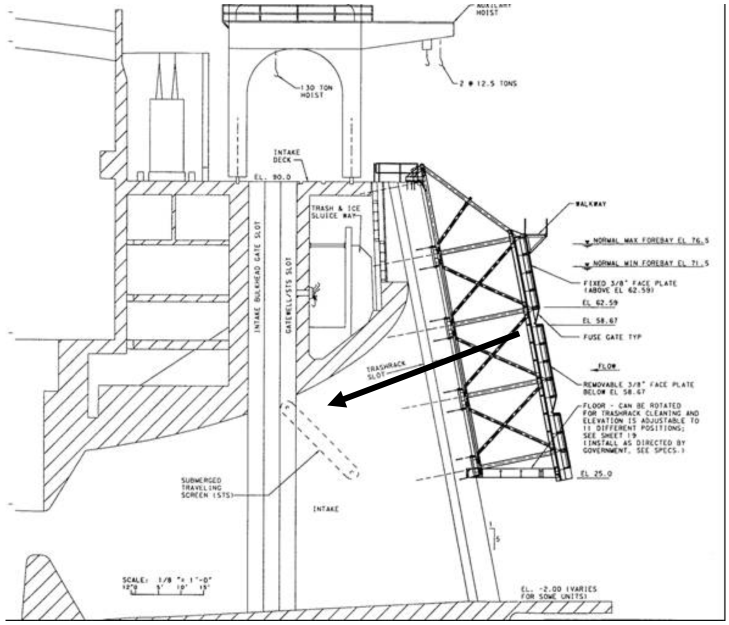


Figure 2. Side view of the PSC at B1. Arrow depicts flow into and through the PSC and into the turbine intake behind. PSC floor was actually installed at El. 30.5 ft, not 25.0 ft. Modified from Plate 4 in Harza and ENSR (1996a).

- In 2000, the PSC was extended from Units 3-6 to also cover Units 1-2, because a noticeable number of smolts were observed in 1998 and 1999 to move obliquely from north to south across the forebay of the PSC. The PSC was thoroughly evaluated in 2000. The objectives for SFO research at B1 in 2000 were to 1) confirm proof-of-concept for surface bypass at B1 that was established in 1998, 2) estimate PSC performance; and 3) study behavioral processes and mechanisms that affect performance to aid future surface bypass designs. The PSC results presented below will focus on the 2000 study because it was the most extensive and the PSC was at its highest level of structural development.

2) What modeling was done?

- Throughout the Corps of Engineers' Surface Bypass Program, physical models have been used to investigate specific design elements in the development process. For the PSC, several design elements were investigated on the B1 1:25 scale sectional utilizing the data such as slot discharge, velocity; sluiceway discharge and headloss into the PSC as well as the immediate downstream hydraulics. The B1 1:40 scale general forebay model targeted general forebay hydraulics (including zone of influence) and 3 dimensional velocities upstream of PSC entrances. CFD data was also used to emulate the entrance conditions of the PSC as well as the immediate downstream hydraulics.

- The hydraulic data below were derived from a 1:25 sectional model
  - Forebay elev. 75 ft
  - PSC floor elev. 30.5 ft
  - Discharge 10 kcfs per unit
  - Flow depends on forebay elevation and turbine operation.

	5-ft	20-ft
Flow* (cfs)	1,700	3,300
Entrance Velocity (fps)	7.1-8.3	3.8-4.6
Area (ft^2)	223	890

- Water velocity in the B1 forebay is generally higher in the north half than the south half. Flow relatively close to Units 1-6 (within 100 ft) had a southerly component. At the PSC, water velocities were about 4-7 fps and had a downward component (Figure 3).

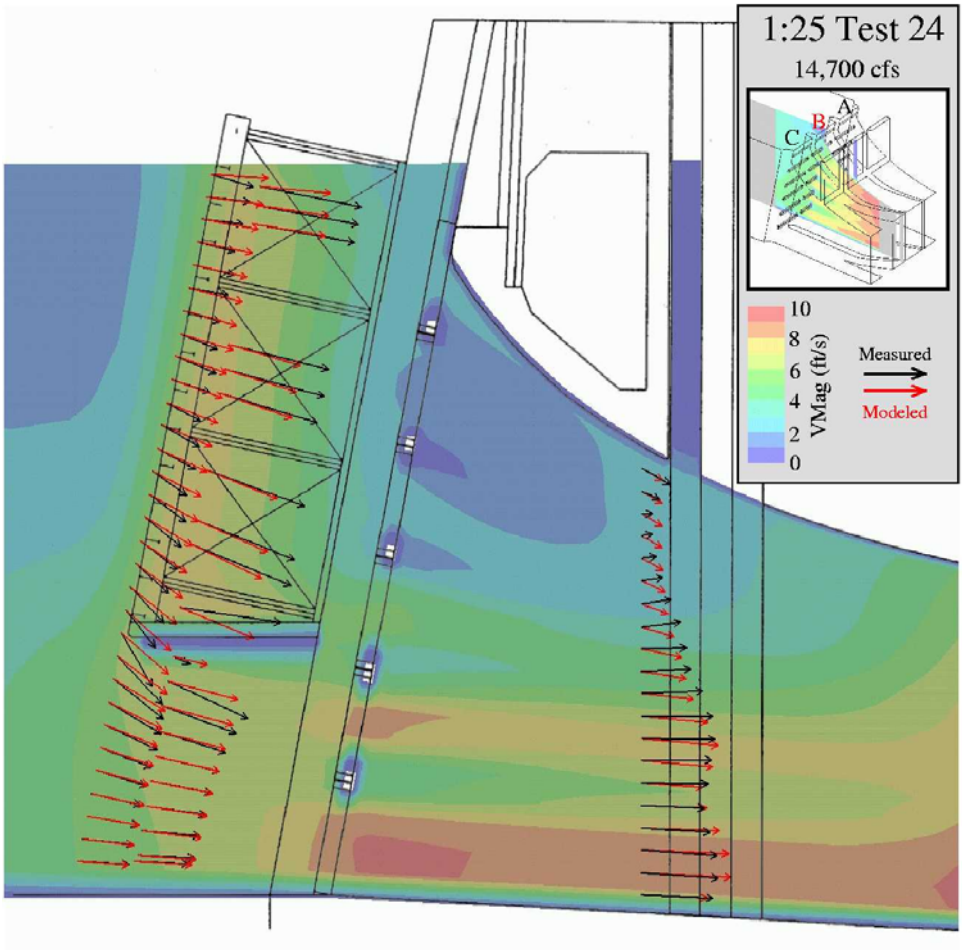


Figure 3. Sectional view of the PSC showing water velocity from a CFD model and a 1:25 scale physical model. Figure courtesy of L. Ebner, CENWP.

3) What were the results of the investigations?

- The 2000 PSC evaluation encompassed PSC efficiency and forebay fish migration patterns, including the following biological research methods:
  - radio telemetry to determine species-specific PSC performance and movement patterns for yearling Chinook salmon and steelhead (Evans et al. 2001)
  - acoustic telemetry to study three-dimensional movement patterns and PSC performance for yearling Chinook salmon and steelhead (Faber et al. 2001)
  - fixed hydroacoustics to estimate fish passage rates and determine PSC performance for the run-at-large during spring and summer (Ploskey et al. 2000)
  - multi- and split-beam hydroacoustics to assess fish movements near the PSC (Johnson et al. 2001)
  - physical scale and computational fluid dynamics modeling to document forebay hydraulic conditions for PSC collection efficiency studies, 2000?.

- Results from the 2000 study (from Johnson and Carlson 2001):

Species	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness
Chinook 1	0.63	0.72	0.43*	2.2*
Steelhead	0.74	0.60	0.45*	2.3*
Run-at-Large Spring	nd	Nd	0.58*	2.9*
Run-at-Large Summer	nd	Nd	0.57*	2.9*

* relative to B1

4) Conclusions from PSC evaluation

- The SFB concept was an efficient way to collect smolts and minimize turbine passage.
- FCE was 45% for steelhead and 43% for yearling Chinook salmon
- Collection efficiency was similar between spring and summer, i.e., it did not decrease in summer, as is the case with other smolt bypass approaches.
- According to radio telemetry data from 2000, had the PSC been a functional bypass system, it would have increased fish passage efficiency at Bonneville Dam 18% for steelhead and 10% for chinook salmon.
- The PSC was eight times as effective (proportion fish divided by proportion water) as spill at passing fish at Bonneville Dam in 2000.

5) *Why was the SFO discarded as a design alternative?*

- Uncertainty about fish response to forebay flow fields from a ramped entrance structure designed to guide fish to a conveyance channel
- Complexity of the conveyance and outfall structures
- Cost (~$230M)

D) SFO Alternative 2 (path to final design or SFO alternative currently being investigated):

Nothing active at this time

1) What modeling and prototype development was done? Present in timeline format.

- A model of the Alternative A (full powerhouse production system) entrance was preliminarily observed on the 1:40 scale physical model of B1. Entrance and immediate downstream conditions for Alternative A were preliminarily compared with the PSC on the 1:25 scale B1 sectional model. The Bonneville 1:100 general model was used to delineate possible outfall sites to be used in a potential full scale production facility (Alternative A).
- An alternatives report examining the feasibility of creating large-scale dewatering facilities, bypass facilities and outfall facilities for juvenile fish collection systems at Bonneville First Powerhouse was undertaken in 1998.
- A study to develop a viable program (or path of study) which outlines, investigates, and develops various methods or options which are possible to proceed with development of the deep slot collection and bypass concept at B1 was undertaken in 2000 (Harza et al, 2001). The recommended program included: further testing of the PSC for optimum slot width and depth; a 1 unit prototype; a 3 unit prototype; and a full production system (approximately $232M). This program path would be compared with other fish passage programs (such as screening and fish bypass systems) to determine the optimum direction to continue in an effort to meet regional fish passage goals.

2) History of development and testing with the decision path.

- n/a

E) Present status of facility:

The PSC has been removed from the dam. B1 Sluiceway is operated in a routine manner for juvenile fish passage.

1) Project layout/bypass system configuration:

- n/a

*2) Cost (**Design**, Construction, Evaluation) of sluiceway and PSC development*
- Not available at this time

3) Biological performance
- n/a

4) Future plans
- Sluiceway improvements
  - Remove JBS wall in channel
  - Increase Q if possible
  - Install 3 automated gates to follow forebay elevation
  - Evaluate fish survival at the existing outfall
- Options for a powerhouse retrofit SFB
  - New conveyance and outfall structures
  - Partial or full powerhouse Alternative A
  - B1 corner collector with BGS
  - Preliminary engineering available

F) Conclusions and lessons learned (from all designs):

1) Data gaps identified
- Uncertainty regarding fish response to forebay flow fields produced from a ramped entrance structure designed to guide fish to a conveyance channel versus the flow fields provided by the PSC with no ramp or collection system.

2) Guiding principles/recipes for success
- Too many PSC evaluation metrics confused people and masked the main point, i.e., high fish collection efficiency.
- Each SFB development effort should be judged on its own merits.
- At a given dam, a long-term regional commitment is necessary to develop a successful SFB.
- We could have used empirical data on fish response to flow fields at SFB entrances.
- The most important data were fish collection efficiencies by species and for the run-at-large.

3) Pit falls, i.e. what not to do
- The limits and capabilities of models used was not always clearly communicated to all stakeholders causing frustration and delay.

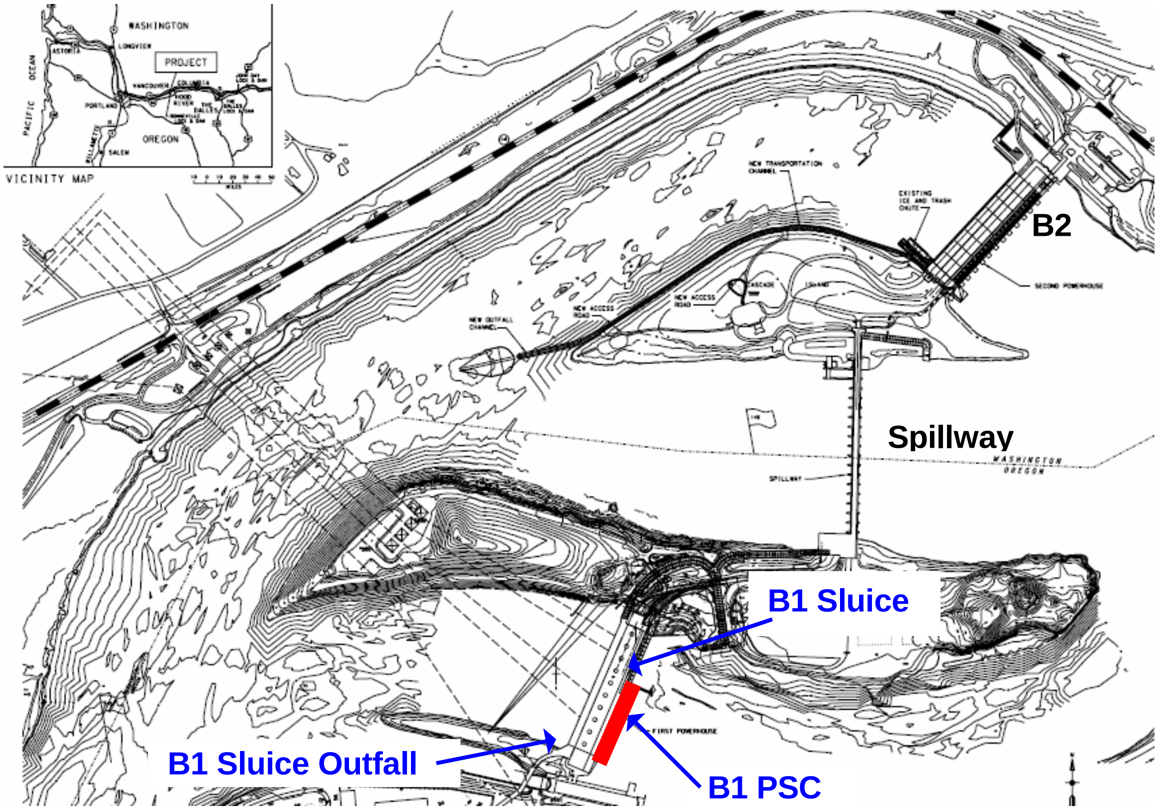
4) Absolute requirements
- Please provide

5) If you had it to do all over again, what would you do differently?
- Ensure that all stake holders are aware of the limits and capabilities of the models used. However, the hydraulic data that was required to interpret biological research data facilitated the development of the first CFD model for Portland District.

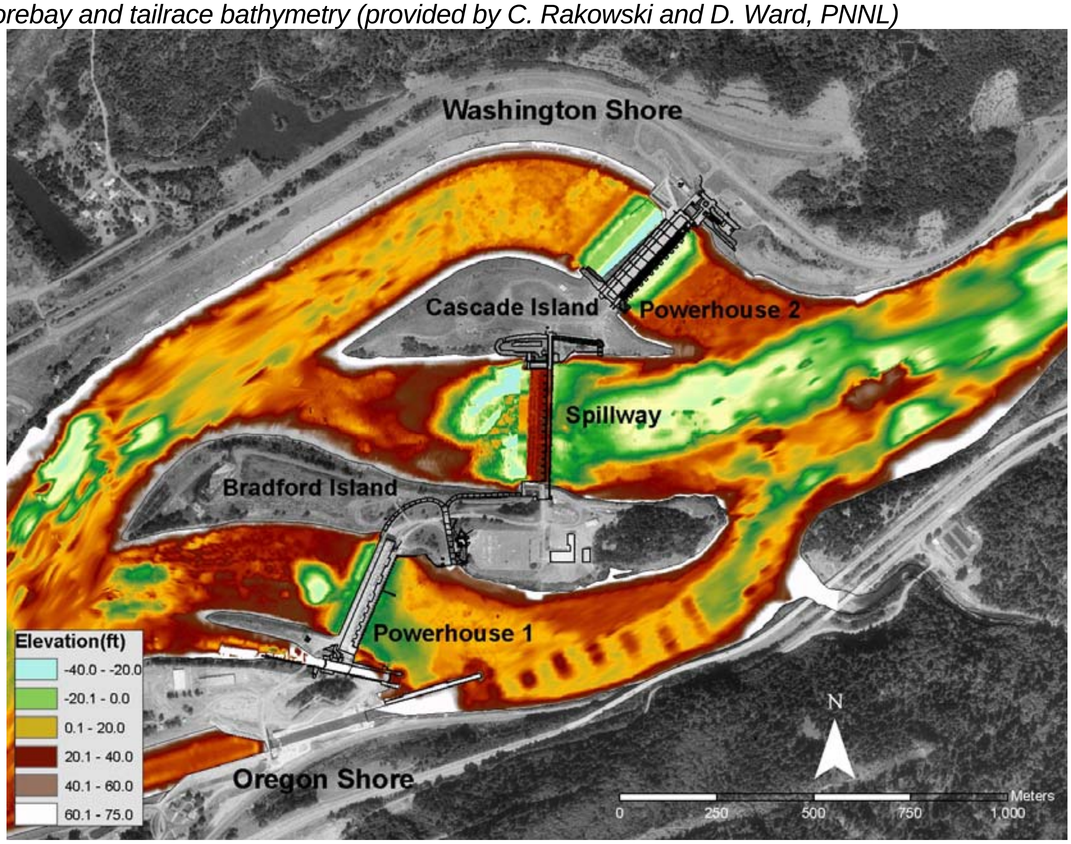
G) Exhibits:

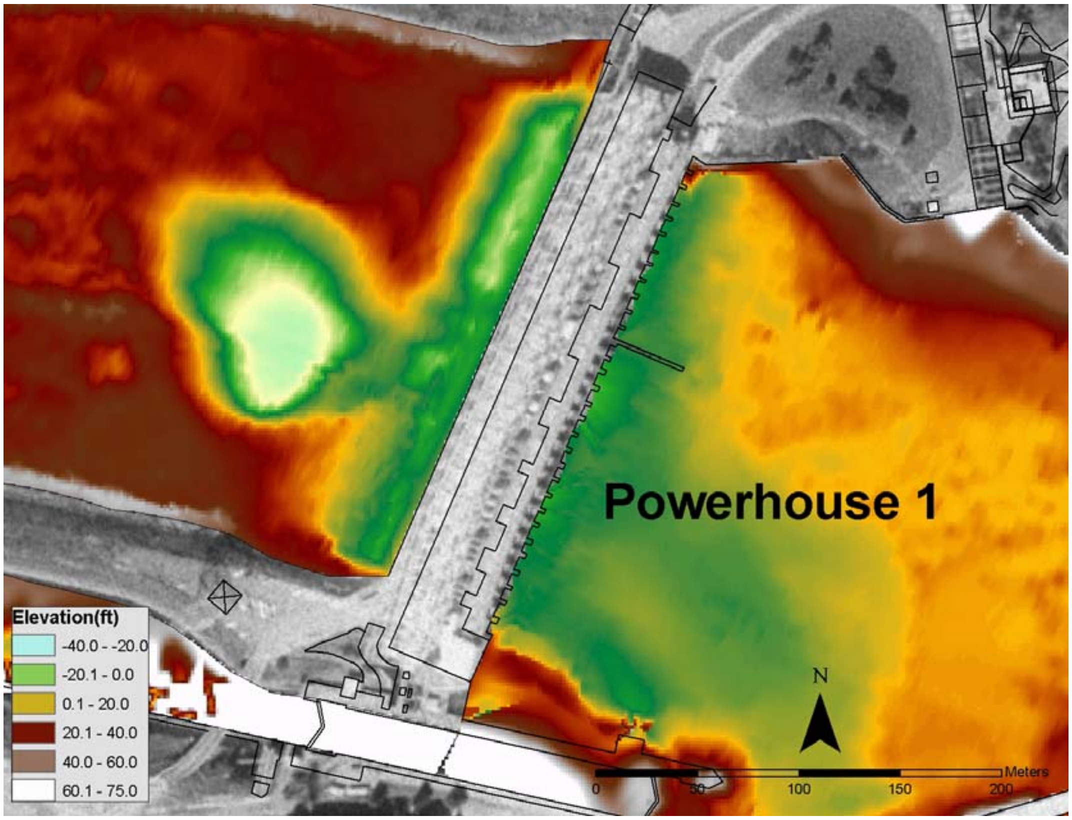
1) Aerial photo

2) *Current project layout with SFO (modified from USACE 2001, B2CC DDR, Plate W1)*

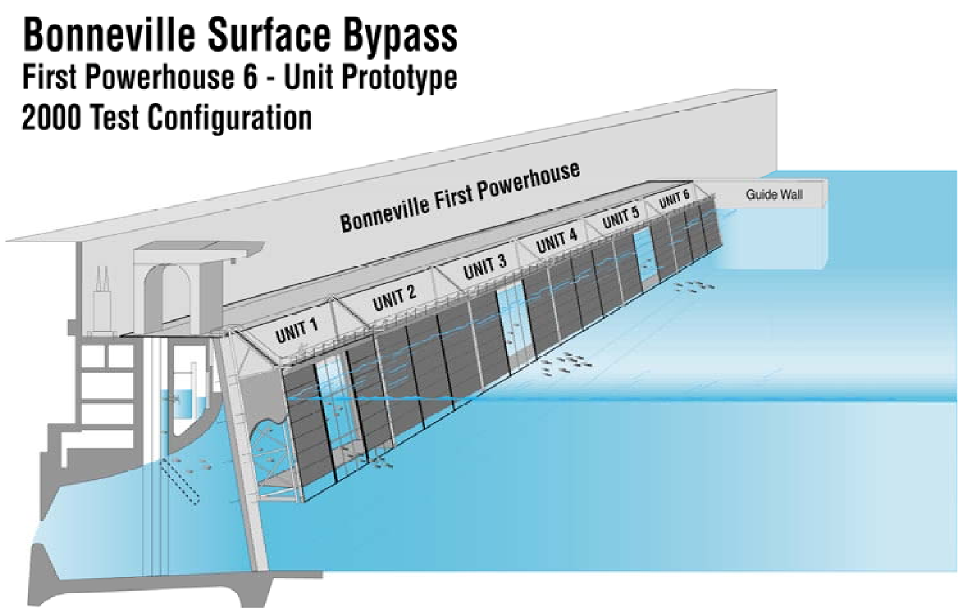


3) Forebay and tailrace bathymetry (provided by C. Rakowski and D. Ward, PNNL)





4) Current plan and profile of the SFO structure



PSC 2000 Test Configuration: PSC structure currently removed from Project

Single Entrance to Ice and Trash Sluiceway: Currently in use

5) *Forebay & tailrace flow fields*

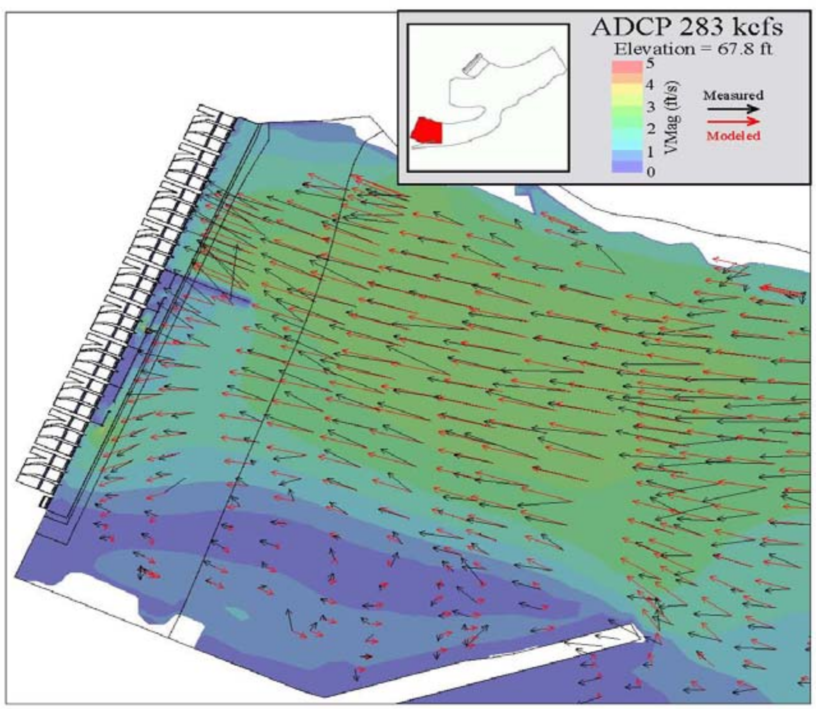


Figure 3.42: Comparison of simulation and measured velocities for the ADCP 283 kcfs data near Powerhouse 1. Plan view at elevation 67.8 ft.

Figure shows example forebay comparison between CFD and ADCP field data

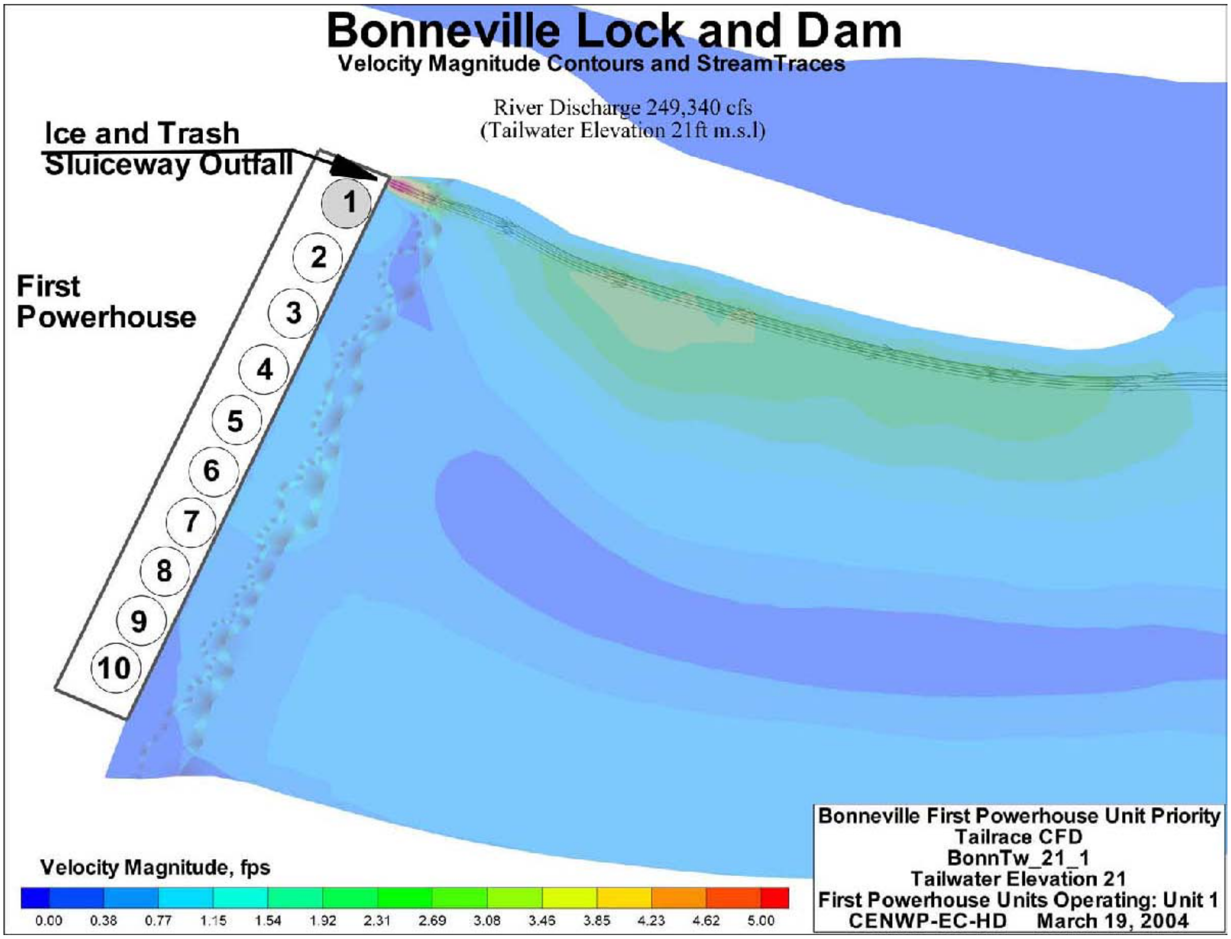


Figure showing example tailrace flow field

Project Description

Project: Bonneville Second Corner Collector

Presenter: ***Blaine Ebberts & Karen Kuhn***

Completed By: Gary Johnson, Karen Kuhn, Blaine Ebberts

Email: Blaine.D.Ebberts@nwp01.usace.army.mil

Phone: 503-808-4763

Date: September 22,2006 (modified by GEJ 1/9/07)

A) Introduction:

1) *Why was SFO considered?*
   - ESA as reflected in Biological Opinions from the National Marine Fisheries Service on operation of the Federal Columbia River Power System.
2) *What initial data kick-started the process?*
   - Project Biologists for Bonneville Dam noted that juvenile salmonids passed into the ice and trash sluice chute when it was opened during migration seasons in the 1980s.
   - A large eddy forms on the southern half of the forebay whose circulation pattern passes in front of the sluice chute.
3) *What SFOs were investigated (model or prototype)?*
   - Baseline passage data were collected at the sluice chute in 1996, 1997 and 1998.
   - Extensive modeling of various intake designs, conveyance features, and outfall siting locations and outfall type designs were investigated.
   - The permanent B2 Corner Collector installed in 2004 used the sluice chute as its basis.

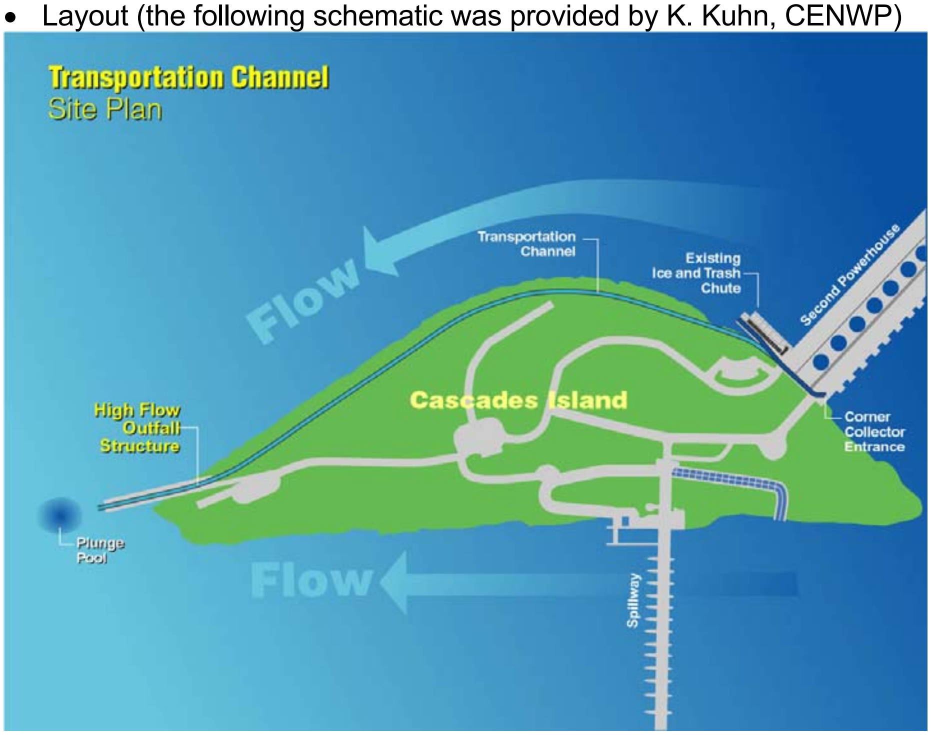
B) Path to Final Design of SFO: B2 Corner Collector

1) *History of development and testing with the decision path*.
   - Harza and ENSR (1995a,b), under direction of the Portland District, identified a number of surface flow outlet alternatives for B2. Development of the sluice chute was one of the alternatives.
   - INCA et al. (1997) used physical scale models to study hydraulic and structural aspects of the sluice chute as a surface flow outlet from biological and engineering perspectives.
   - CH2M-Hill et al. (1998) did preliminary engineering for a physical guidance device at the beginning of the B2 forebay channel with the goal of diverting juveniles toward the spillway and away from the B2 forebay.
   - In 1996, 1997 and 1998, the sluice chute was opened for biological research using improved monitoring methodology to re-evaluate its passage potential. Given the encouraging results of the 1998 biological studies (presented below), fisheries managers and the Corps committed to development of the B2CC.
   - PNNL et al. (2001) developed preliminary guidelines for high flow outfalls.
   - INCA et al (2001) performed a B2CC outfall type and site selection study in the design phase of the engineering process utilizing physical and CFD modeling.
   - Johnson et al. (2000) studied biological and hydraulic characteristics of high flow outfalls (> 1,000 cfs), like the one being developed at the time for the B2CC.
   - USACE (2001) concluded the engineering phase with a Design Documentation Report.
   - The construction phase for the new entrance gates, conveyance channel, and outfall for the B2CC was completed in 2004.
   - PNNL (Ploskey et al. 2005) and USGS (Reagan et al. 2005; Evans et al. 2005) evaluated B2CC biological performance during 2004 and 2005.
   - Today, the B2CC is permanent, functional surface flow outlet that is routinely operated as a complement to the intake screen system for smolt protection at B2.

2) *What modeling and prototype development was done?*
- 1995-1997 – A 1:100 scale general physical model of Bonneville Dam was used to interrogate the forebay and tailrace of B2 for surface collection development.
- 1997 – Sluice chute entrance shapes, floor elevations, modifications to the dam face and powerhouse operations were studied in the 1:40 scale forebay physical model of B2 identifying flow patterns, zone of influence, entrance velocities and rating curves (INCA et al. 1997).
- 1999-2001 – High flow outfall location siting, outfall type selection, and high flow outfalls guidelines research utilized the 1:100 scale general physical model of Bonneville Dam and a 1:30 scale physical model of the outfall and plunge pool.
- 1999-2004 – Computational Fluid Dynamic (CFD) modeling of the tailrace and the entrance/ogee was used in consort with physical modeling for alternatives investigation as well as final design. In addition, study of forebay characteristics at the entrance to the B2CC for optimizing powerhouse operations utilized CFD modeling.
- 2000-2001 – Entrance and ogee dynamics were examined in the 1:40 scale model for final design along with one dimensional numerical modeling throughout the conveyance structure.
- 2005 – Post construction model runs for multiple Project operational scenarios were completed on the 1:100 scale general physical model of Bonneville Dam.

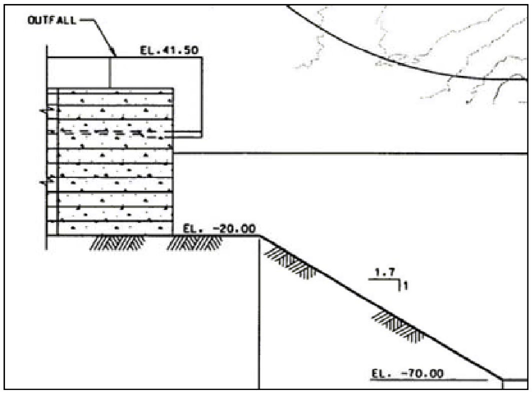
C) Present status of facility:

1) *Project layout/bypass system configuration*
- Improvements to the sluice chute to create the B2CC
  - Entrance (new gate and hoists, usable entrance changed from el. 61 ft. to el. 52 ft)
  - Conveyance Channel (ogee added to achieve acceptable fish conveyance through 23 ft. drop in floor, 45 deg bend, and clearance below overhead UMT crossing, then re-route channel and extend 2766 ft. to downstream outfall location)
- Outfall and engineered plunge pool (designed for efficient fish egress and minimal fish injury).
- Layout (the following schematic was provided by K. Kuhn, CENWP)

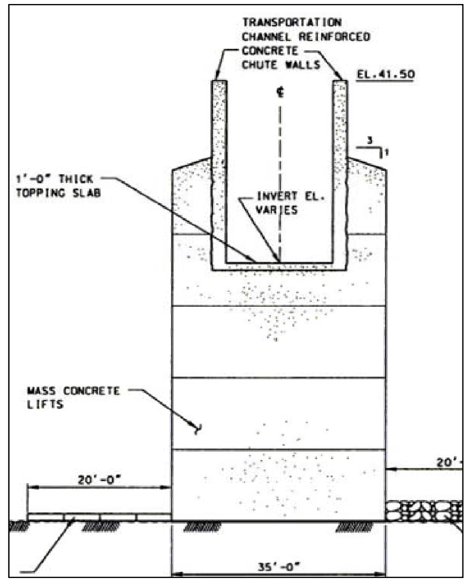


- Outfall (from INCA et al. 2001)

Side View



End View



2) *Cost*
- Design development (model, engineering and field studies, alternative development and analysis, decision process): $5M
- Engineering and Design (DDR, P&S, EDC): $6M
- Construction: approx. $35M
- Evaluation: approx. $4M
- Total: approx. $50M

3) *Biological performance*
- Route-specific survival estimates for the B2CC were nearly 100%. (See following table)
- Fish collection efficiency for the B2CC was highest for hatchery steelhead trout at 66-74% (see following table). The B2CC passed 37% of the yearling Chinook salmon in both years studied. Subyearling Chinook salmon collection efficiencies were variable between the two years at 29 to 40%. For the run-at-large, summer migrants had higher efficiencies than spring migrants (40-44% vs. 31-32%, respectively). Fish collection effectiveness was 13-14 for steelhead and about 1/3 to ½ that for the other species. The results were reasonably consistent between the two sampling techniques and the two study-years.

Table. Fish collection efficiency and effectiveness for the B2CC during the post-construction evaluation in 2004 and 2005. Radio telemetry was used for estimates for yearling Chinook salmon, steelhead trout, and subyearling Chinook salmon. Hydroacoustics were used for estimates for the run-at-large in spring and summer. Data from: FCE: Evans et al. 2005;: Farley et al. 2006; Regan et al. 2005; Regan et al. 2006; Surv. Counihan et al. 2006, Ploskey et al. 2005; Ploskey et al. 2006 (table 3.1, p.3.17).

Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate
Chinook 0	2004	nd	nd	0.37	5.6	1.010
	2005	nd	nd	0.40	5.9	1.020
	mean			0.39	5.8	1.015
Chinook 1	2004	nd	nd	0.37	7.0	1.020

Species	Study-Year	Discovery Efficiency	Entrance Efficiency	Fish Collection Efficiency	Fish Collection Effectiveness	Direct Survival Rate
	2005	nd	nd	0.29	5.9	1.020
	mean			0.33	6.5	1.020
Steelhead	2004	nd	nd	0.74	14.2	1.010
	2005	nd	nd	0.66	13.2	1.010
	mean			0.70	13.7	1.010
Run-at-Large Spring	2004	nd	nd	0.31	5.8	nd
	2005	nd	nd	0.32	5.8	nd
	mean			0.32	5.8	
Run-at-Large Summer	2004	nd	nd	0.40	8.2	nd
	2005	nd	nd	0.44	6.8	nd
	mean			0.42	7.5	

4) *Future plans*
- Log boom perhaps to simulate guidance structure, i.e., LGR BGS.
- New entrance structure, possibly.
- Something to pass more yearling and subyearling Chinook salmon.

D) Conclusions and lessons learned (from all designs):CENWP

1) *Data gaps identified*
- At the beginning of the studies, there were little to no guidelines that pertained to high flow outfalls.

2) *Guiding principles/recipes for success*
- Coordination, communication, and commitment among all stakeholders to proceed on a reasonable schedule and plan very early in the process. Then revisit that schedule and plan often.

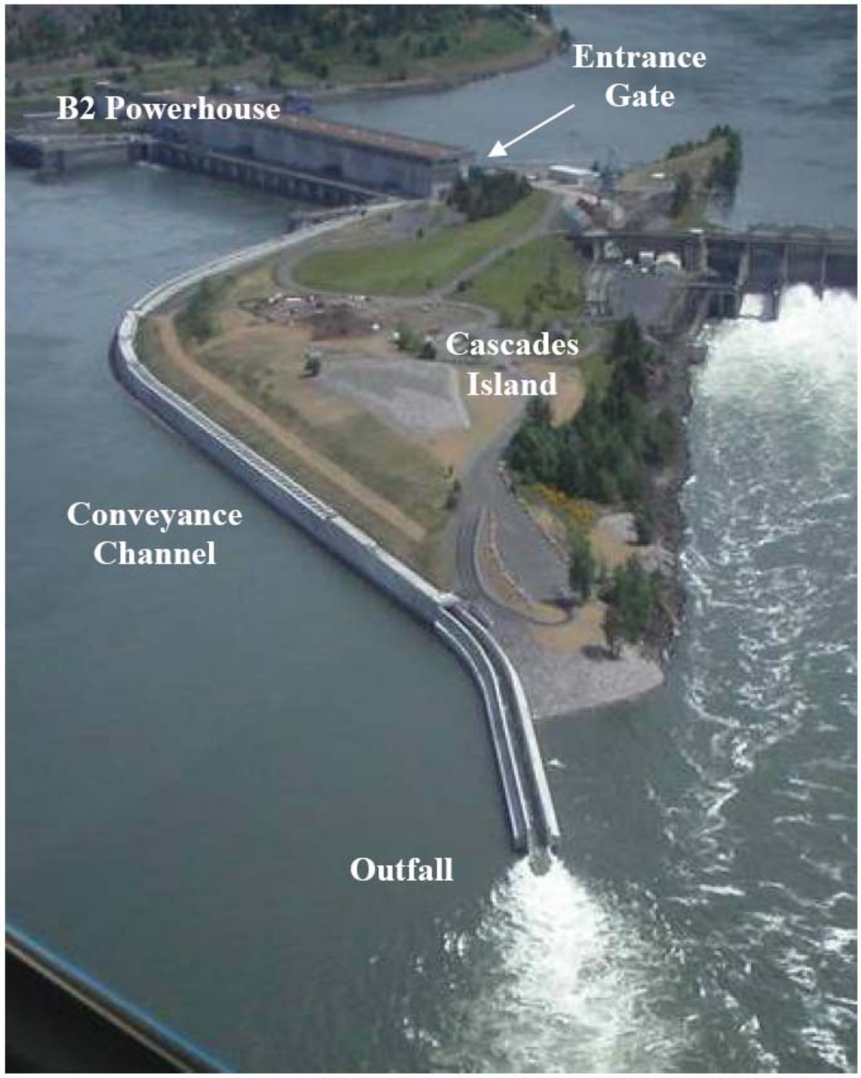
3) *Pit falls, i.e. what not to do*
- Don't let the cart drive the horse: decision and design steps should proceed in a logical sequential progression whenever possible and not be forced into multiple concurrent tasks that do not allow for optimization of the whole.
- When a large project requires breaking up tasks into manageable sections, pay attention to details of how the sections fit together periodically throughout the process.

4) *Absolute requirements*
- Final design should precede plans and specifications to avoid limiting design options if "surprises" are revealed in the hydraulic modeling effort.

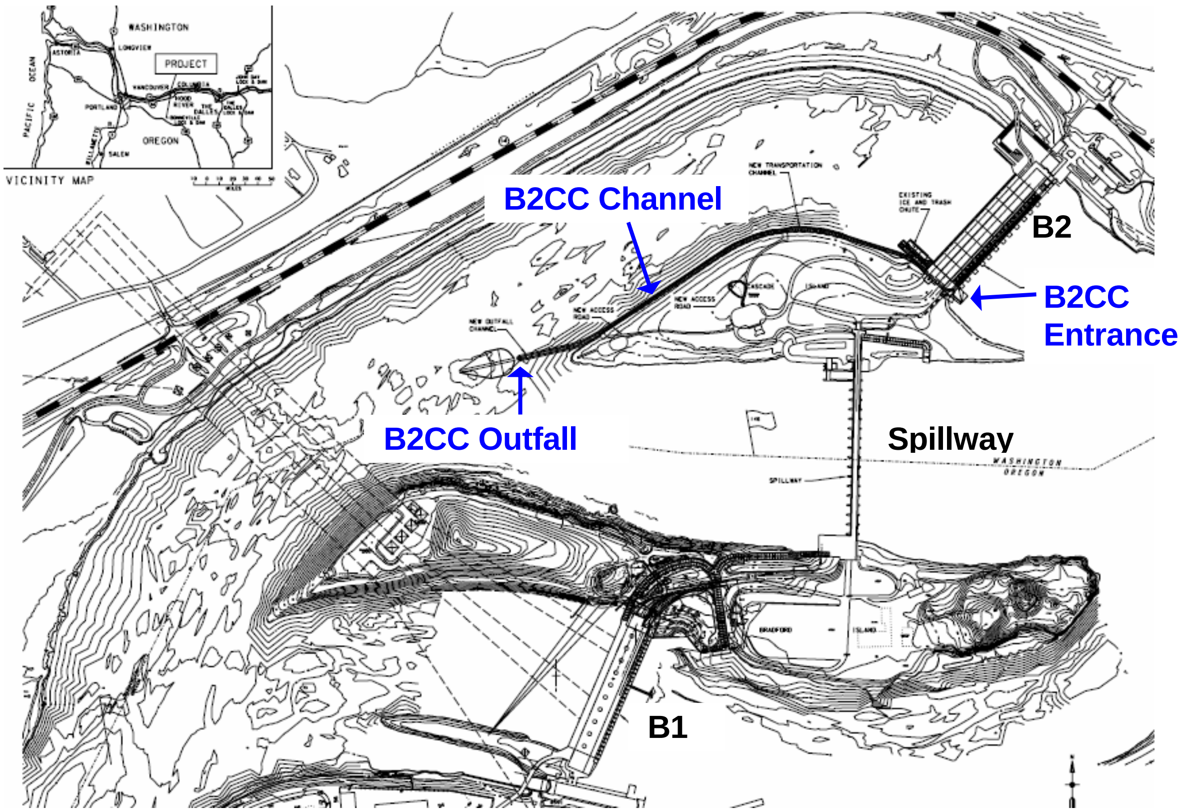
5) *If you had it to do all over again, what would you do differently?*
- Explore existing information and define guidelines earlier in the process before attempting design studies.
- Have a complete design before starting Plans and Specifications.

E) Exhibits:

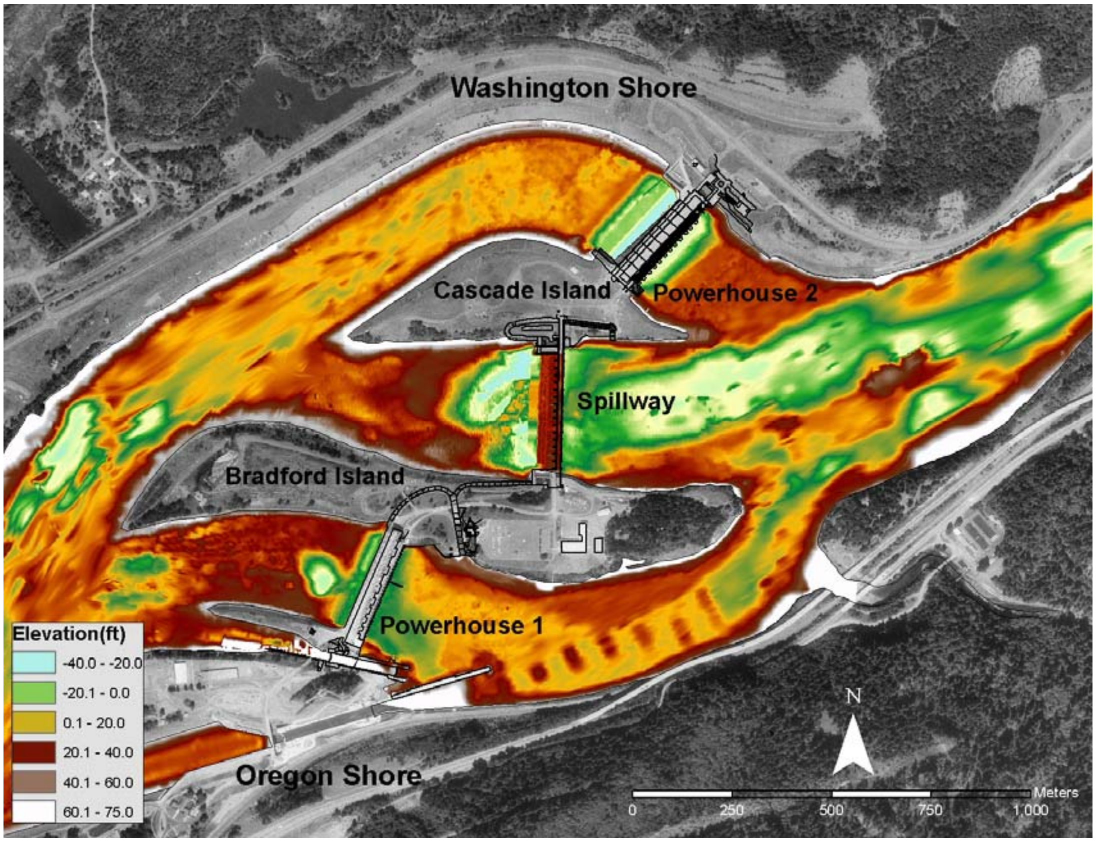
1) Aerial photo (modified from a photograph provided by K. Kuhn, CENWP)

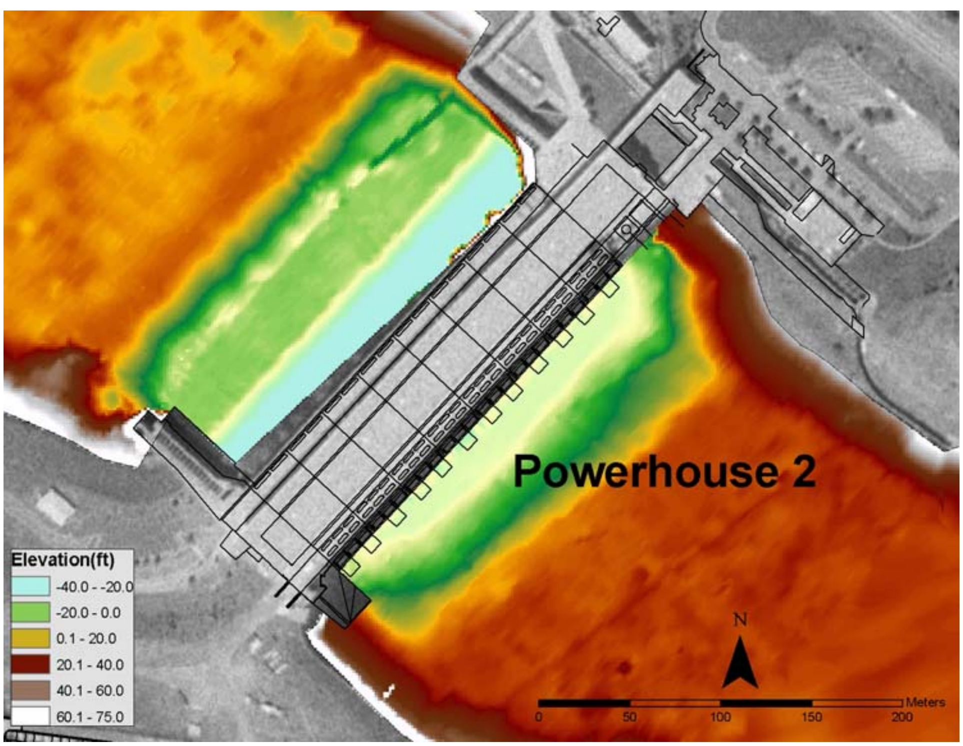


2) Current project layout with SFO (modified from USACE 2001, B2CC DDR, Plate W1)



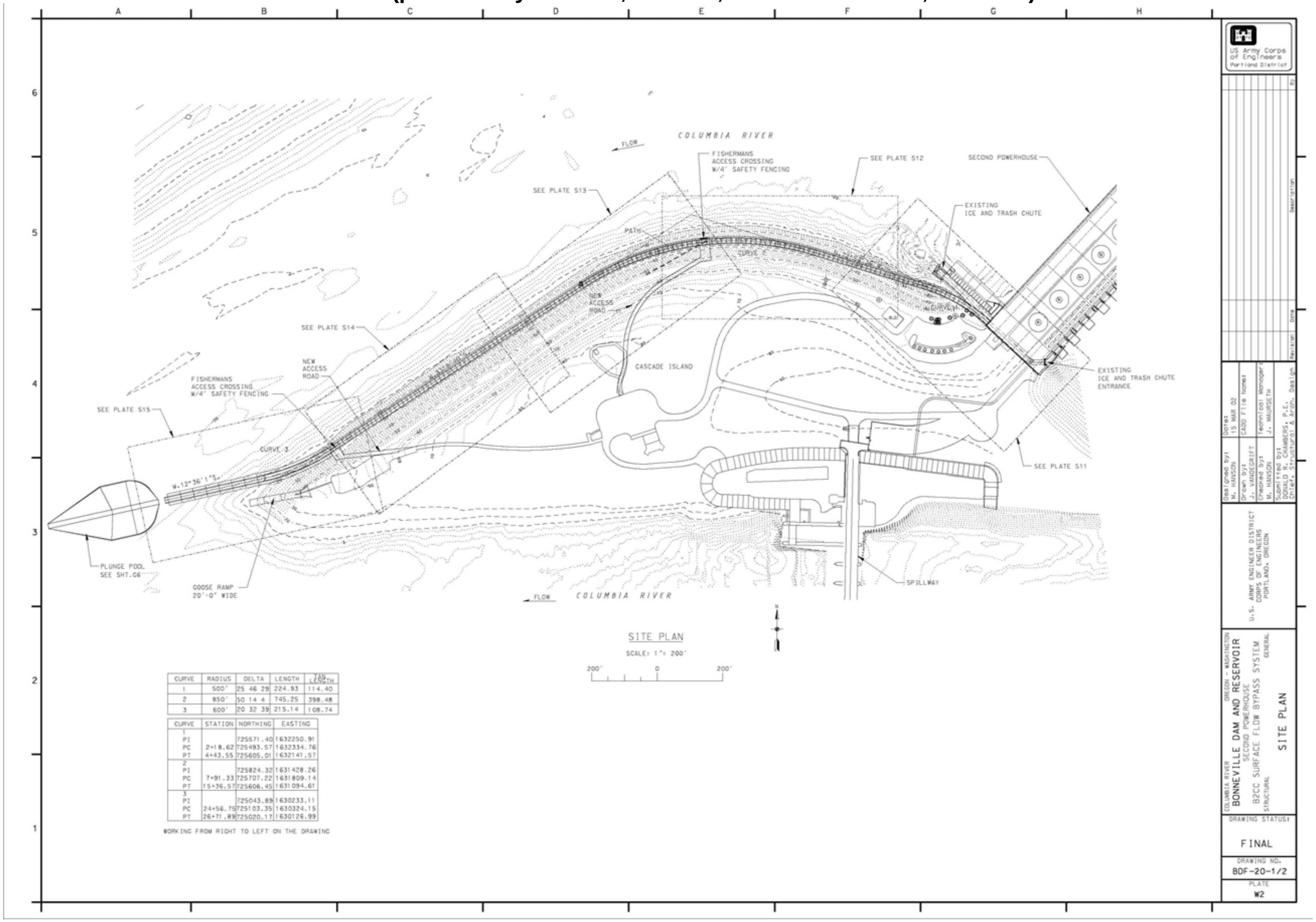
3) *Forebay and tailrace bathymetry (provided by C. Rakowski and D. Ward, PNNL)*



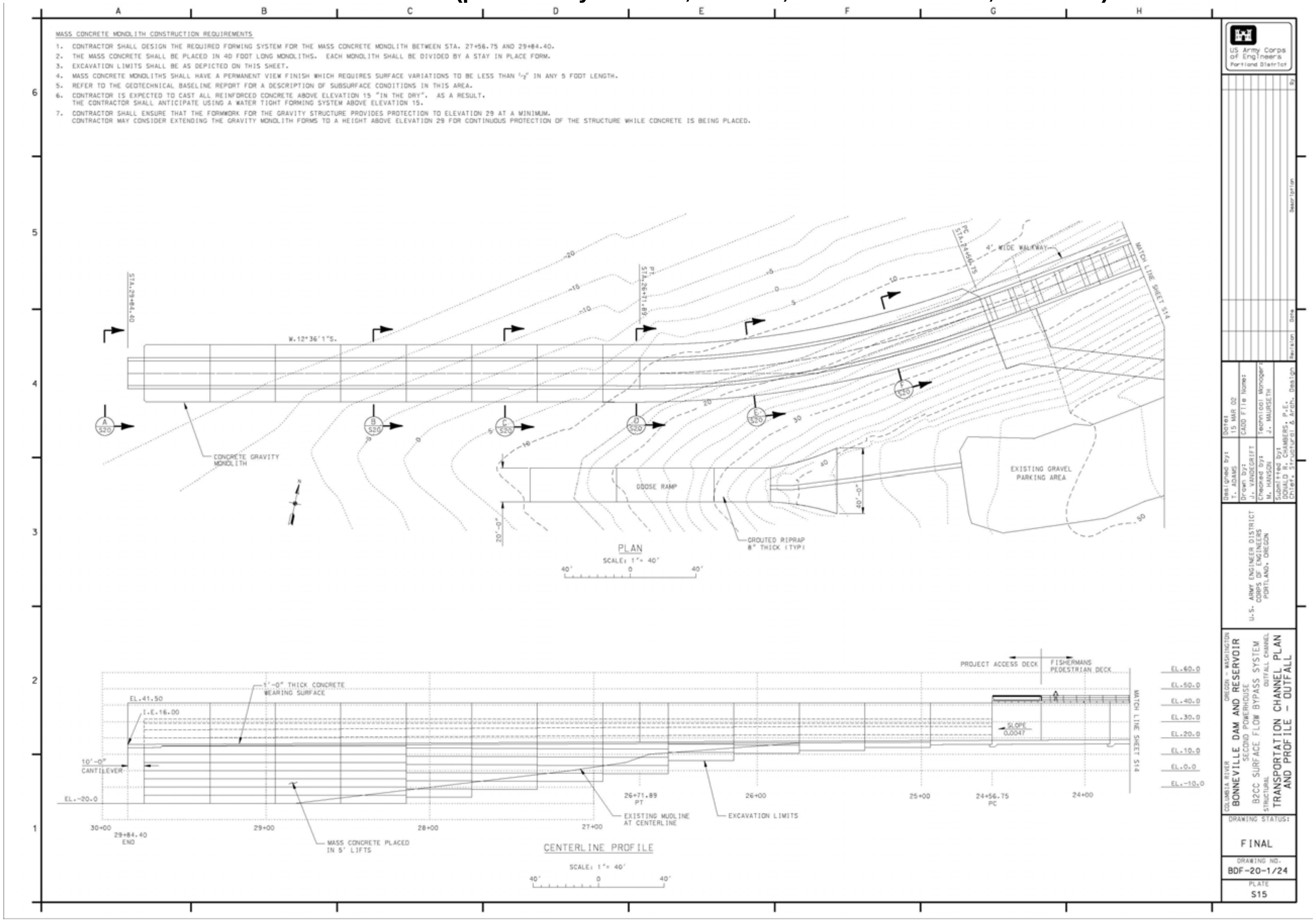


4) *Current plan and profile of the SFO structure*

Plan View (provided by K. Kuhn, CENWP, from USACE 2001, Plate W2)

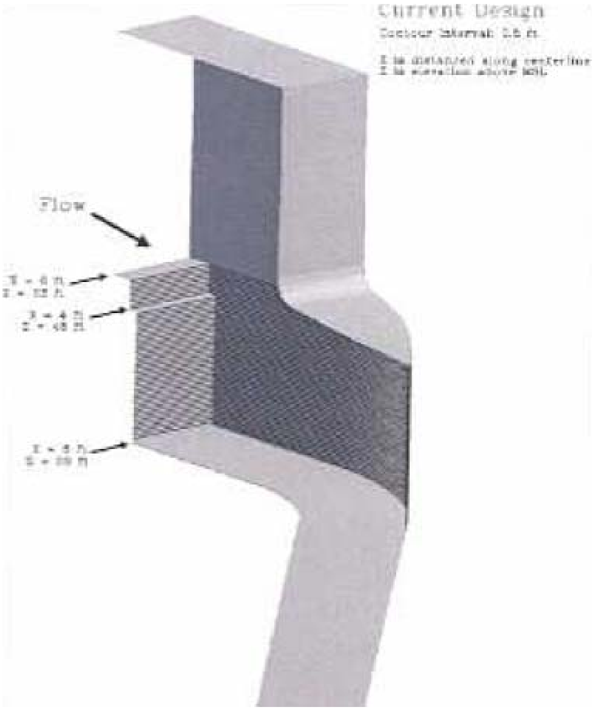


Plan and Profile Views (provided by K. Kuhn, CENWP, from USACE 2001, Plate S15)

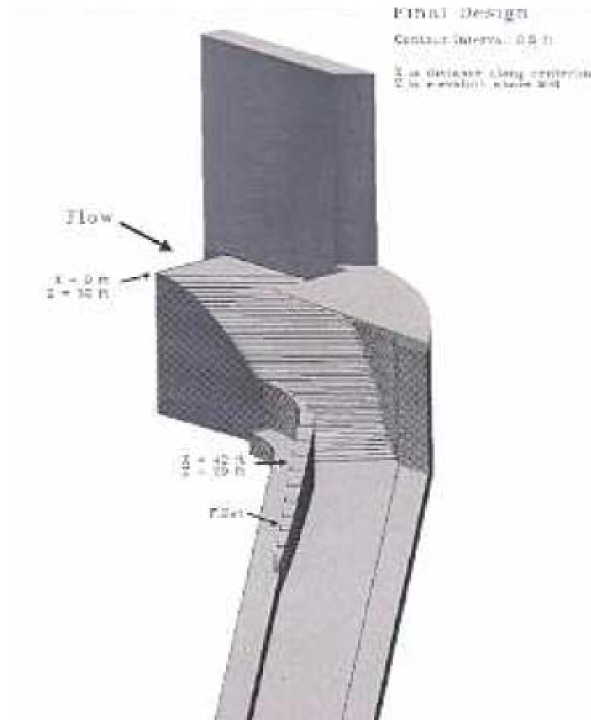


Ogee – Annex C.4 pp. 10-11

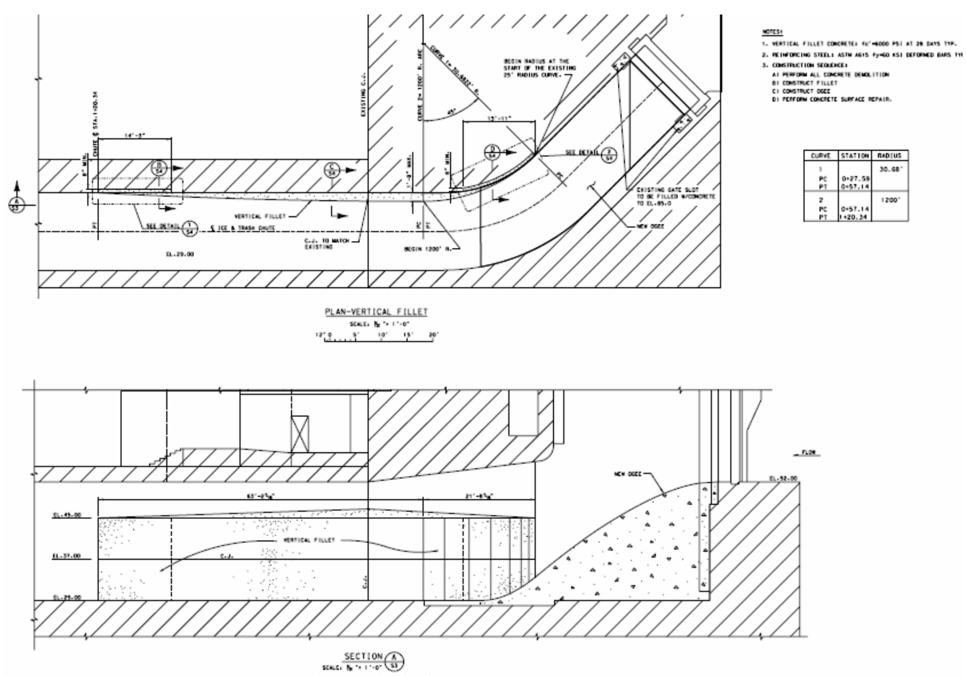
Before



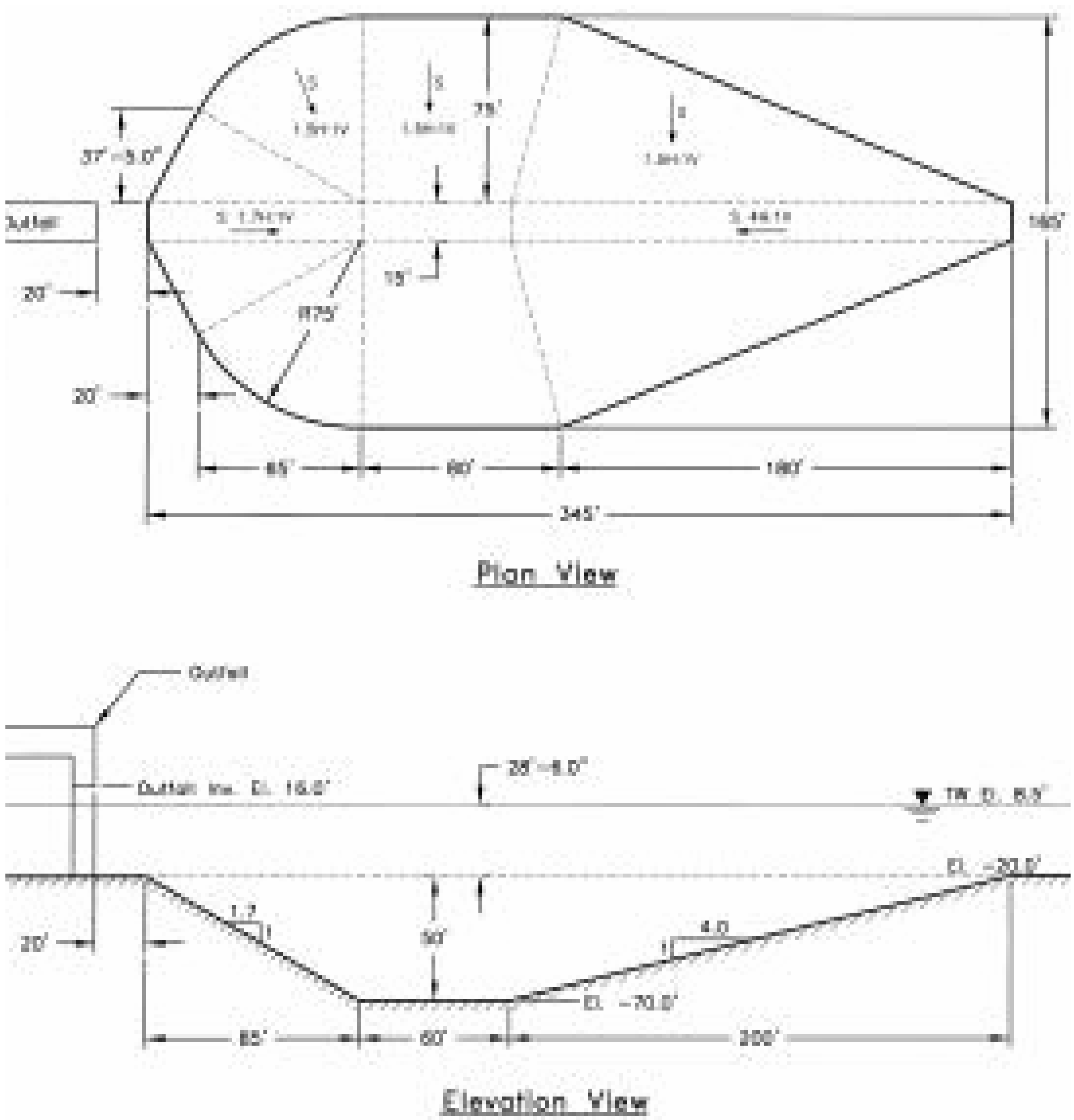
After



Vertical Fillet Ogee – USACE 2001 B2CC DDR—Plate S3

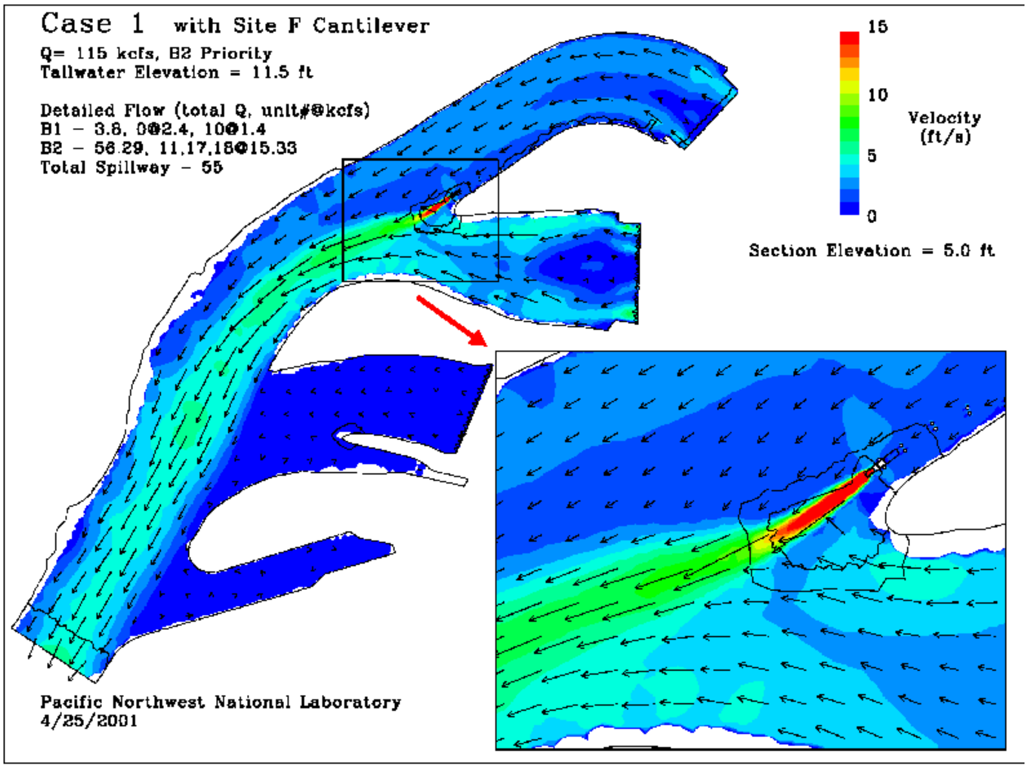


Outfall Plunge Pool – USACE 2001 B2CC DDR, p. 3-25

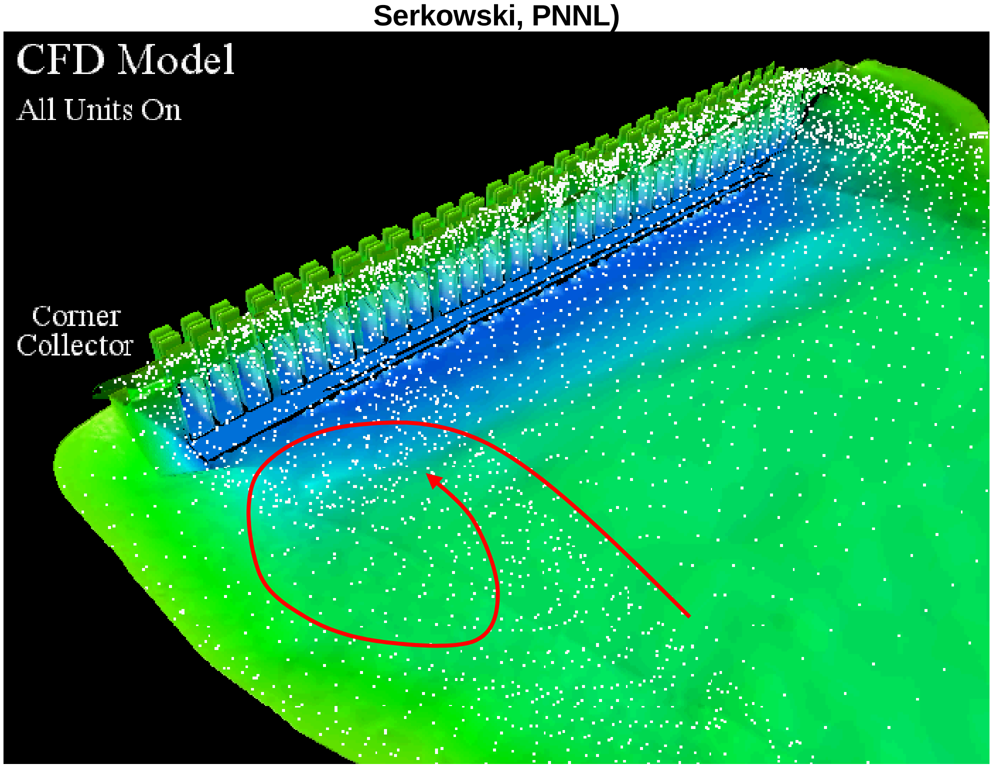


5) ***Forebay & tailrace flow fields***

Example Tailrace (provided by L. Ebner, CENWP)



Example Forebay (modified from image obtained from a CFD movie provided by J. Serkowski, PNNL)



Project Description

Completed By: Mark LaRiviere

Email: mlarivie@cityoftacoma.org

Phone: 253.502.8767

Date: 10/6/2006

Project: Mayfield Dam louver collection and bypass (Cowlitz River)

Presenter: ***Mark LaRiviere (Tacoma Power)***

A) Introduction:

1) *Why was SFO considered?*
   - The surface collection and bypass facility at Mayfield Dam, Cowlitz River has been operational since 1963. The relicensing of the Cowlitz Hydroelectric Project in the 1990's looked at the existing facility and a formulated a recommendation to make improvements to the facility, to continue with the operation and to evaluate it annually.
2) *What initial data kick-started the process?*
   - License compliance studies were begun in 2001 prior to the issuance of the license, but following a comprehensive settlement agreement (SA) that included proposed license articles.
     - In 2001 a CFD study of the louver bays, and a fish guidance efficiency study of hatchery coho smolts were conducted using HTI acoustic tags. The results of the FGE study with a sample size of 30 fish were: 67% FGE.
   - In 2002 a turbine survival study were conducted using Normandeau & Associates turbine tags. The survival results (after 48 hours) were:
     - Steelhead
       - Unit 41 mean = 82.6%
       - Unit 44 mean = 97.1%
     - Coho
       - Unit 41 mean = 84.7%
       - Unit 44 mean = 97.1%
   - Combing the FGE and the turbine survival results into a calculation that accounted for the rare spill occurrence at Mayfield Dam (< 3% annual flow over a 10-year average), the overall survival of smolts passing Mayfield Dam (as defined in the SA) was 93% to 95%. The goal is 95% for all species.
3) *What SFOs were investigated (model or prototype)?*
   - The existing louver guidance system in place at Mayfield Dam.

Complete the following for each SFO identified in A.3. that was ultimately discarded

---

B) SFO Alternative 1 (investigated and ultimately discarded):

1) *What modeling and prototype development was done? Present in timeline format.*
   - These tasks were completed in the 1950s.
2) *History of development and testing with the decision path (testing, design considerations, performance, etc)*
   - Extensive modeling and testing was completed in the 1950s.
3) *Why was the SFO discarded as a design alternative?*
   - The louver collection system was built and has been functional since 1963.

Complete the following for each SFO identified in A.3. that is currently in use or under development

---

C) SFO Alternative 3 (path to final design or SFO alternative currently being investigated):Fish Guidance Louver System

1) *What modeling and prototype development was done? Present in timeline format.*

- See answers to A 2) above.

2) *History of development and testing with the decision path*.
   - The Computational Fluid Dynamics (CFD) modeling work was done to characterize the louver and bypass entrance hydraulics in 2006. One species of smolt was evaluated with acoustic telemetry study in 2001 to calculate FGE and to assess patterns of movement through the louver intake system.

D) Present status of facility:

1) *Project layout/bypass system configuration:* Fish Guidance Louver System
   - Two large V-shaped vertical louvered entrances (North and South entrances) guide fish to an 8 inch bypass slot.
   - From the bypass slot fish are guided into either the north or south entrance bypass pipes and delivered to a secondary dewatering unit (separator).
   - The fish are then transported downstream of the dam to a collection facility or directed into a transport pipeline that discharges at the powerhouse tailrace.
2) *Cost (Design, Construction, Evaluation)*
   - Original capital costs were included with the Mayfield Dam upstream passage facilities. In 1967 the City of Tacoma costs were $7.0 million.
   - The evaluation studies conducted in 2001/2002 of the Mayfield Dam louver collection system were $584,040.
3) *Biological performance*
   - Fish Guidance Efficiency (FGE) Results

Species	1964	1965	MEAN	2001
Coho	.495	.617	.56	.67
Chinook	.757	.74	.75	
Steelhead	.736	.793	.77	

Fish Passage Survival (FPS) Results

Species	2006
Coho	93%
Chinook	93%
Steelhead	95%

4) *Future plans*
   - Planned Improvements
     - Debris management
     - Louver bay hydraulics
     - Secondary separator screen & baffles
     - Counting house remodel
     - Discharge chute upgrade

E) Conclusions and lessons learned (from all designs):

1) *Data gaps identified*
   - Current estimates of the FCE for spring Chinook, cutthroat and steelhead yearlings and fall Chinook sub yearlings. Also, estimates of FCE for all species and all life stages at varying spring and summer flow releases from Mayfield Dam.
2) *Guiding principles/recipes for success*
   - Achieving a 95% downstream fish passage survival rate at Mayfield Dam. The FPS is defined as "Downstream fish passage survival rate" as used in proposed license article 2 and applied to Mayfield Dam, means the percentage of smolts entering the Mayfield louver system that are guided through the juvenile fish guidance and bypass facilities and do not enter the turbines, plus those juveniles that also pass through the project turbines or over the spillway and also survive.
3) *Pit falls, i.e. what not to do*

- None identified.

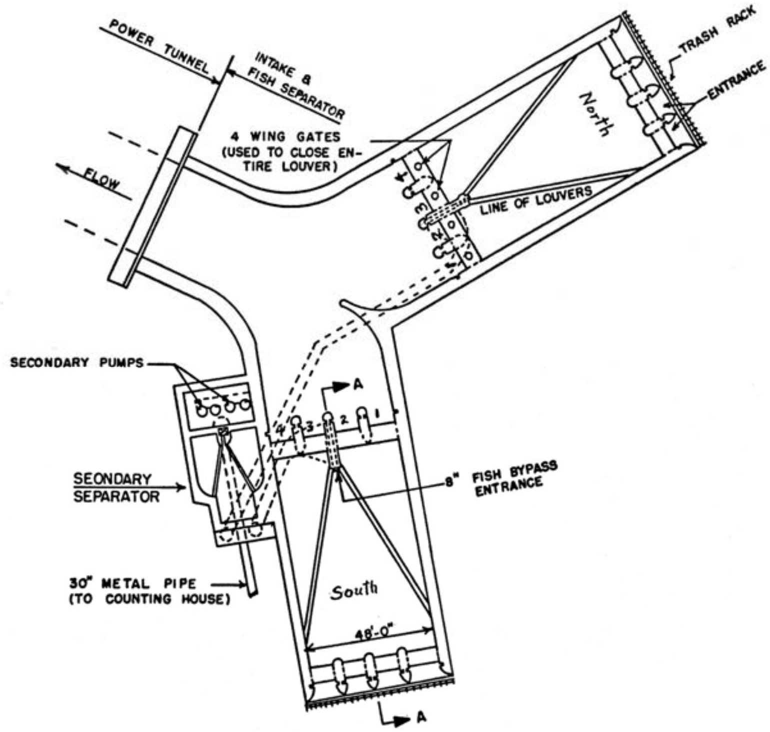
4) *Absolute requirements*
   - Providing the opportunity for continual downstream migrant passage year round.
5) *If you had it to do all over again, what would you do differently?*
   - Improved record keeping. Sampling of the different races of species encountered at the collection facility for genetic differences.

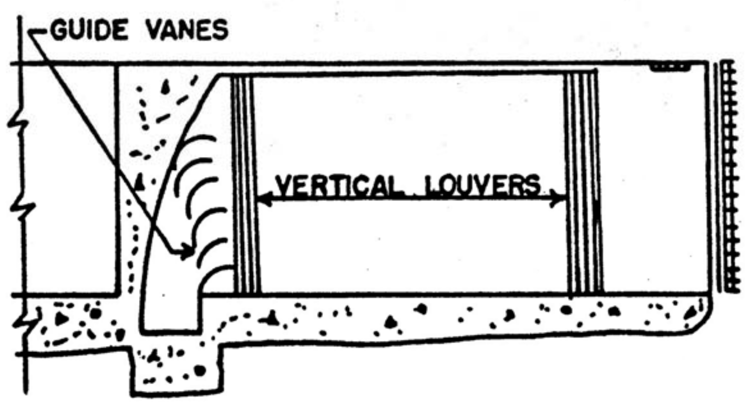
F) Exhibits:

1) *Aerial photo*

2) *Current project layout with SFO* (Not currently available)
3) *Forebay and tailrace bathymetry* (Not currently available)

4) *Current plan and profile of the SFO structure*





5) *Forebay & tailrace flow fields*

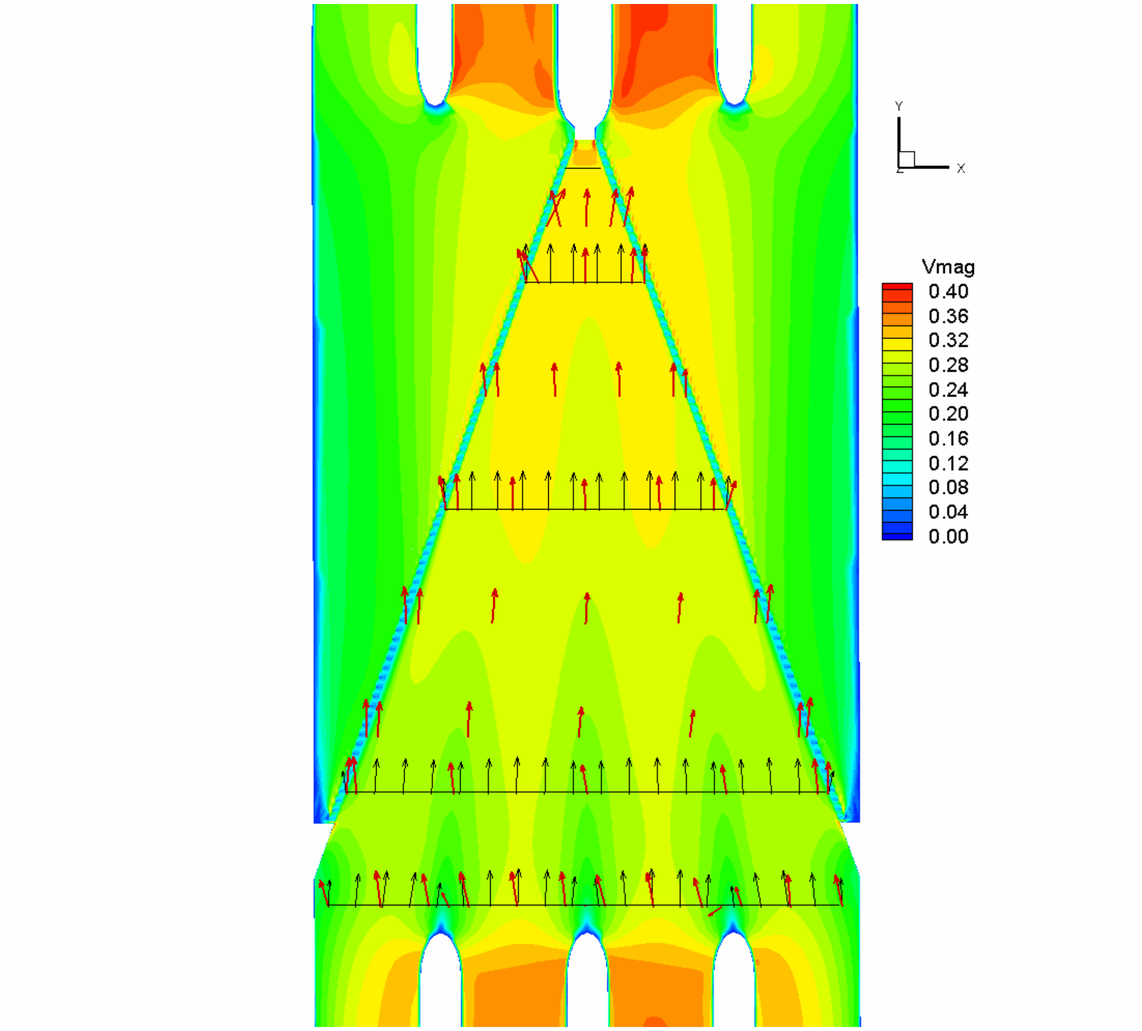


Figure 1: Mayfield Dam louver system verification run 01 - zoom view (Q=1290 cfs, elev. 395.6 ft, Vmag in m/s)

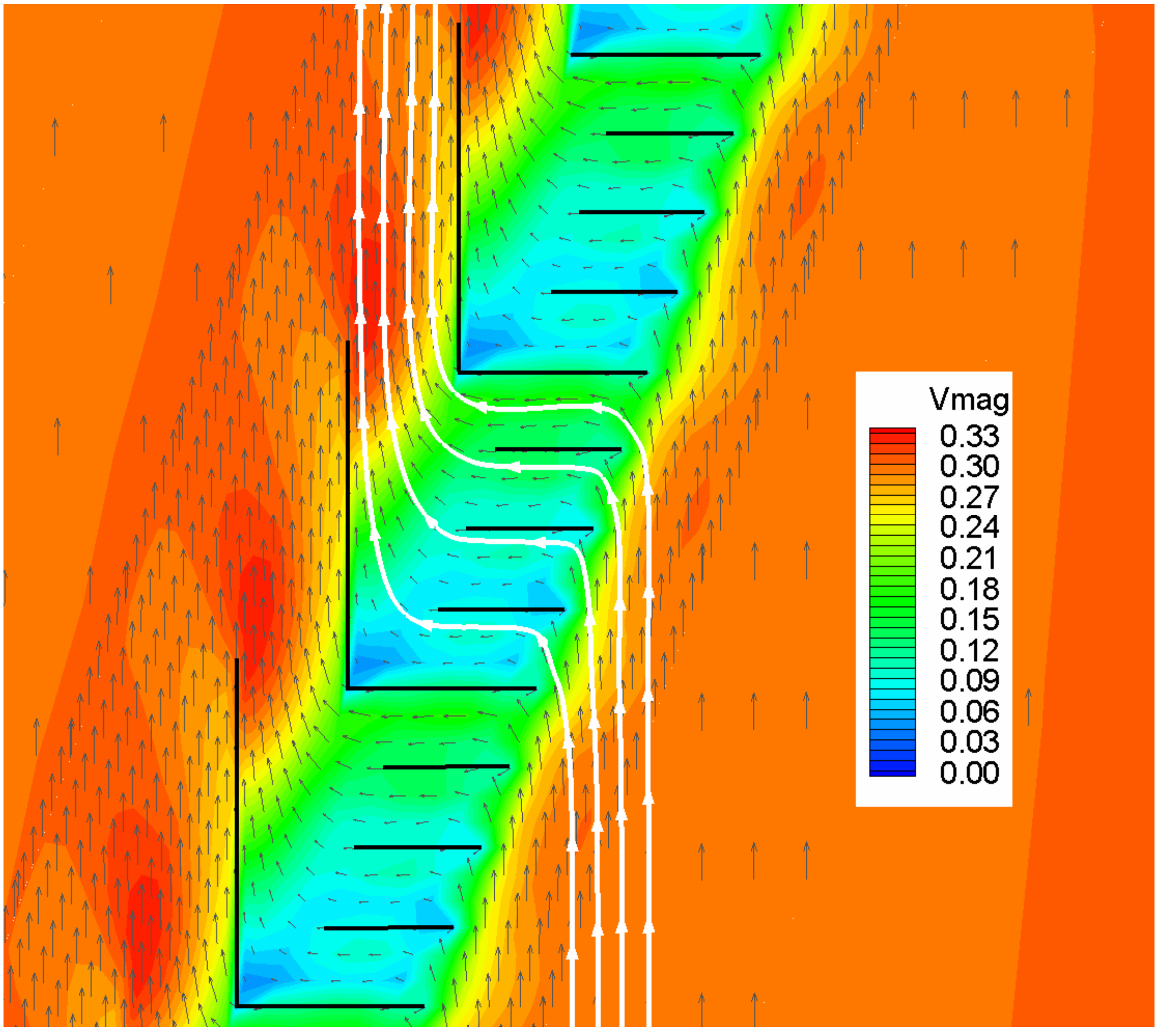


Figure 2: Mayfield Dam verification run 01- louver vanes zoom (Q=1290 cfs, elev. 395.6 ft, free-slip louvers, Vmag in m/s)

–

Project Description

Project: Cowlitz Falls (Cowlitz River)

Presenter: ***Steve Fischer (Tacoma Power)***

Completed By: Steve Fischer

Email: sfischer@ci.tacoma.wa.us

Phone: 253-502-8316

Date: 12/1/06

A) Introduction:

1) *Why was SFO considered?*
   - Original designs implemented at Cowlitz Falls dam were based on Wells dam and consisted of baffle panels with a narrow and very deep transition screen. The screen was abandoned for a number of reasons and then work was done on finding the best baffle panel configuration to attract fish. Data indicated that a high percentage of the fish were currently being attracted into the area between the baffle panels and the spillway gate fish flumes. The fish were, however, rejecting the abrupt flume entrances at the spillway gate face. It was thought that we simply needed to provide the proper transition (meeting NOAA criteria) from the low velocity area to the higher velocity flume flow to achieve success.
   - 3-yrs to achieve fish passage survival goals of 75%-95%
   - Proposed Bypass System Goals:
     - Fish collection flow of 100 to 400 cfs
     - Attraction velocity at baffle panel of 0.5-1.4 fps
     - Smooth transport of fish from reservoir to flumes
     - Meet NOAA criteria:
       - Screen approach velocity component ≤ 0.4 fps
       - Sweeping velocity component > approach component
       - Transport velocity gradient in screen channel ≤ 0.2 fps/ft
2) *What initial data kick-started the process?*
   - There were years of data from LCPUD/BPA in tracking fish and trying different configurations of baffle panels to get fish near the spill gates. These studies encouraged us to us a wide and somewhat deeper entrance to the fish screen.
3) *What SFOs were investigated (model or prototype)?*
   - Entrance bulkhead
   - Fish Transition Screen

Complete the following for each SFO identified in A.3. that was ultimately discarded

---

B) SFO Alternative 1 (investigated and ultimately discarded): Entrance Bulkhead?

1) *What modeling and prototype development was done? Present in timeline format.*
2) *History of development and testing with the decision path (testing, design considerations, performance, etc)*
3) *Why was the SFO discarded as a design alternative?*

Complete the following for each SFO identified in A.3. that is currently in use or under development

---

C) SFO Alternative 3 (path to final design of current SFO alternative): Fish Transition Screen

1) *What modeling and prototype development was done? Present in timeline format.*
   - BPA construction of fish collection facility and original fish screen
     - Removal of fish screen
     - 10 years of work to find best configuration with existing facilities
     - Baffle panel configuration tests
     - Flume entrance tests
   - CFD modeling:

- @ 250 cfs attraction flow
- Existing Conditions 3000 cfs Unit 2 Flow

2) *History of development and testing with the decision path*.
   - Field Testing and Adjustment Iterations
     - Measured and integrated velocities at 7 measurement cross sections
     - Determined flow through each screen panel
     - Calculated average approach velocity at each screen panel
     - Adjusted backing plate porosity to balance approach flow velocities
     - Performed 5 iterations over 1 week
     - Verified with point velocity measurements along screen panel vertical centerline with final porosities.

Panel	Distance From Downstream End (in)	Elevation (ft)	Approach Velocity Component (ft/s)	Sweeping Velocity Component (ft/s)
2	42	852.6	0.35	1.05
2	28	852.6	0.31	1.08
2	14	852.6	0.17	1.32
3	30	854.6	0.35	1.85
3	20	854.6	0.26	1.91
3	10	854.6	0.09	1.99
4	42	856.6	0.41	2.25
4	30	856.6	0.37	2.26
5	40	858.6	0.34	2.91
5	23	858.6	0.27	2.75
5	14	858.6	0.26	2.79
6	29	858.6	0.29	3.11
6	18	858.6	0.13	3.20

D) Present status of facility:

1) *Project layout/bypass system configuration: RSW / Modified BGS*
   - Cowlitz Falls has a hydrocombine design similar to Wells Dam
   - Current system has a V-shape fish screen deployed in the spillway to guide fish to existing fish gate bypass flume.
2) *Cost (Design, Construction, Evaluation)*
   - Total to Date; $1,660,000
   - Design & Modeling $550,000
   - Construction 650,000
   - Evaluation $460,000
3) *Biological performance*
   - USGS:
     - Radiotelemetry
     - DIDSON Camera
     - Mark Recapture
   - Fish Collection Efficiency (Radiotelemtery):
     - Steelhead 52%
     - Coho 31%
     - Spring Chinook 19%

- Results were about the same as with no screen
- 2006
  - Steelhead 45.1%
  - Coho 22.1%
- Other Observations
  - 34% of Coho and 21% of steelhead were detected at the debris barrier and then passed through turbines.
  - Coho showed strong tendencies toward deep passage (78%).
  - Fish were attracted to the screen entrance where milling behavior was observed.
  - Fish entered screen to later reject it.
  - Screen retention and milling in the screen increased after shading was applied directly over the screen (Chinook).
- Summary and Conclusions
  - Screen meets NOAA flow criteria
  - High fish encounter efficiency
  - Low fish retention efficiency
  - Rejection occurs about 30 feet into screen

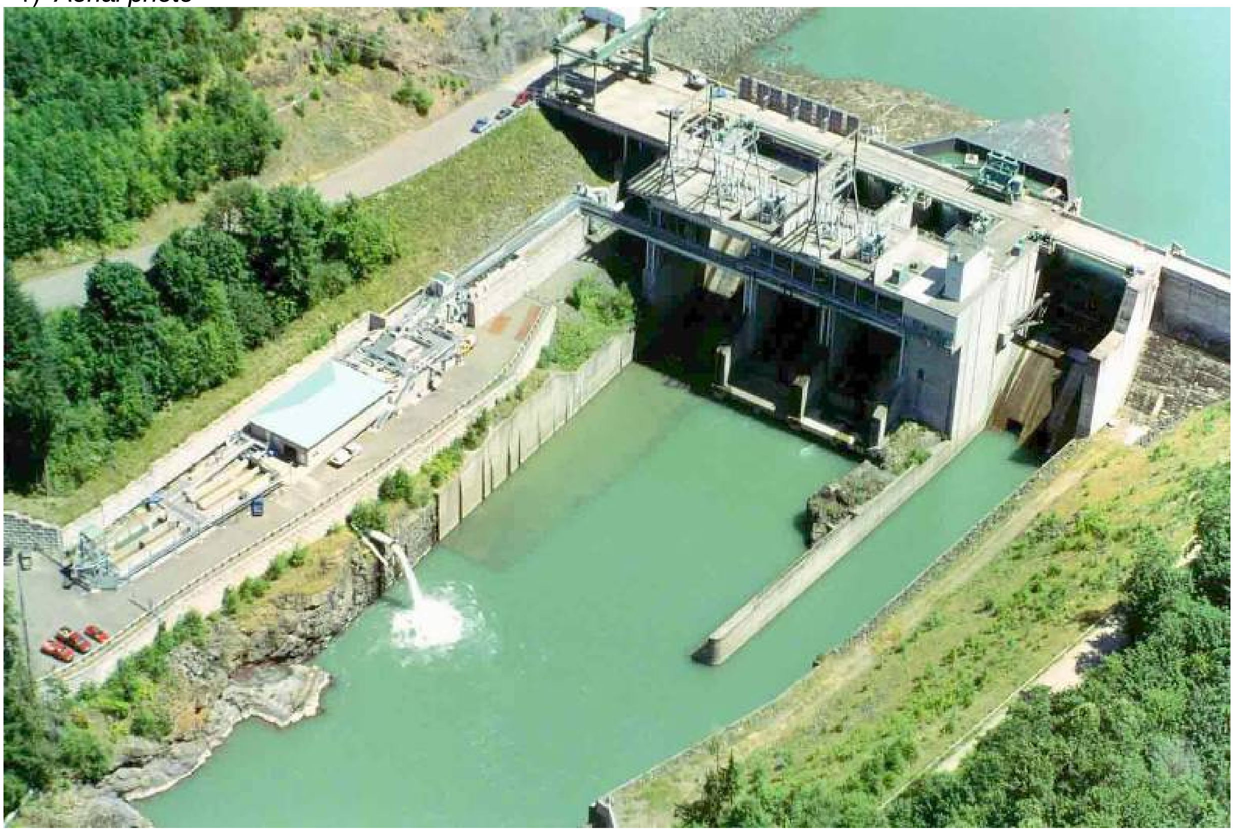
4) *Future plans*
   - Doing hydraulic adjustments with DIDSON camera observations to see if that will improve fish retention
   - Experimenting with shading
   - Proposed system bypass goals
     - Screen meets NOAA flow criteria
     - High fish encounter efficiency
     - Low fish retention efficiency
   - Entrance rejection occurs about 30 feet into screen

E) Conclusions and lessons learned (from all designs):

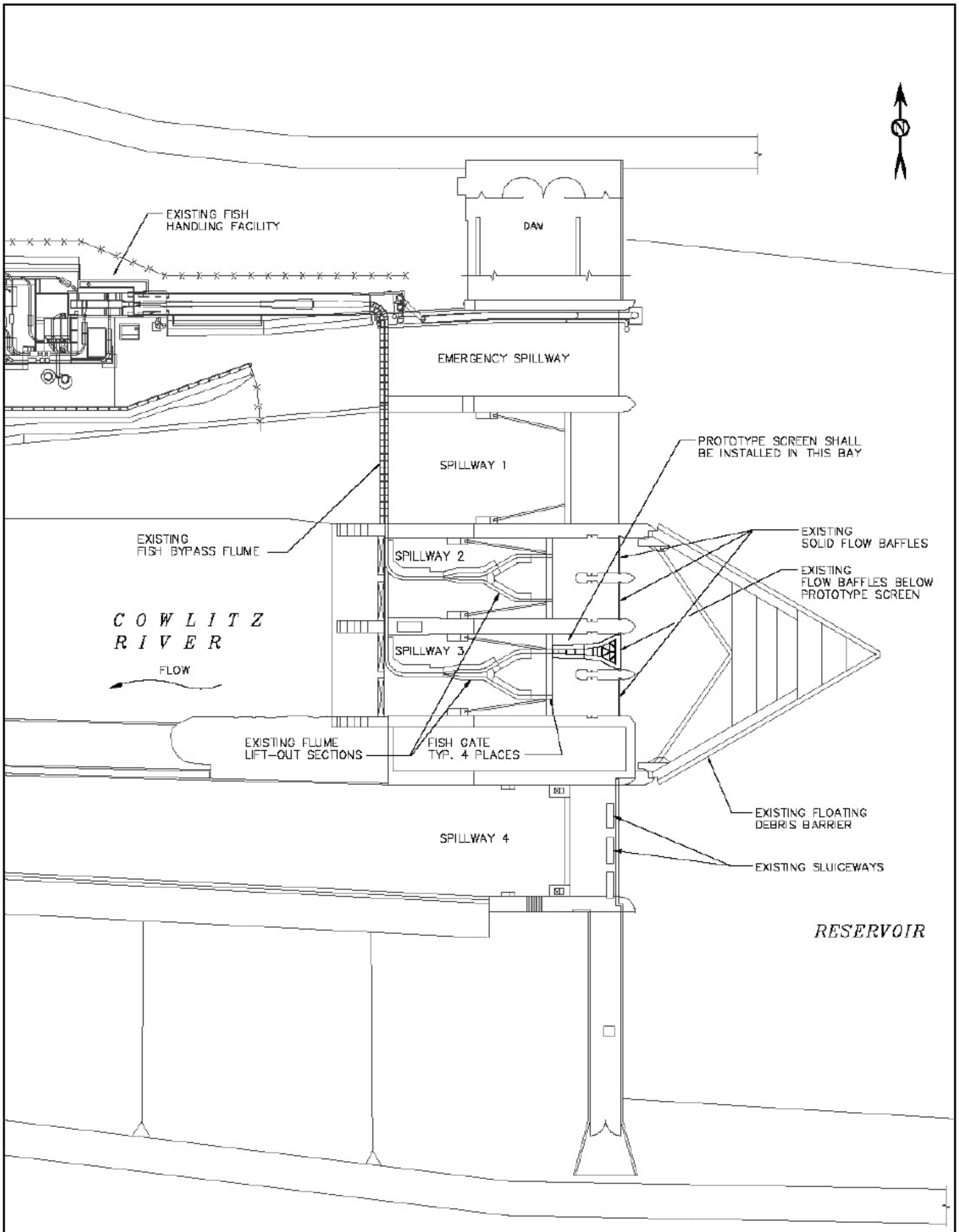
1) *Data gaps identified*
2) *Guiding principles/recipes for success*
3) *Pit falls, i.e. what not to do*
4) *Absolute requirements*
5) *If you had it to do all over again, what would you do differently?*

F) Exhibits:

1) *Aerial photo*

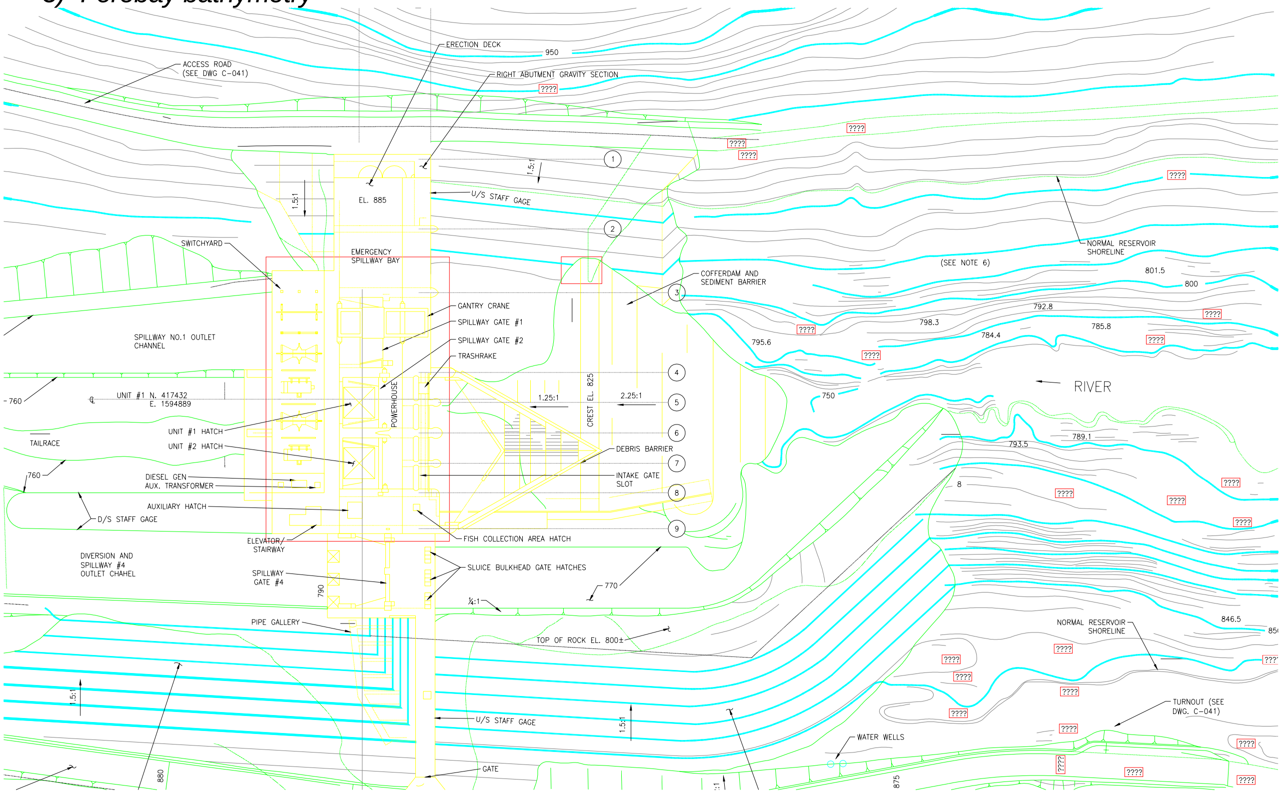


2) *Current project layout with SFO*

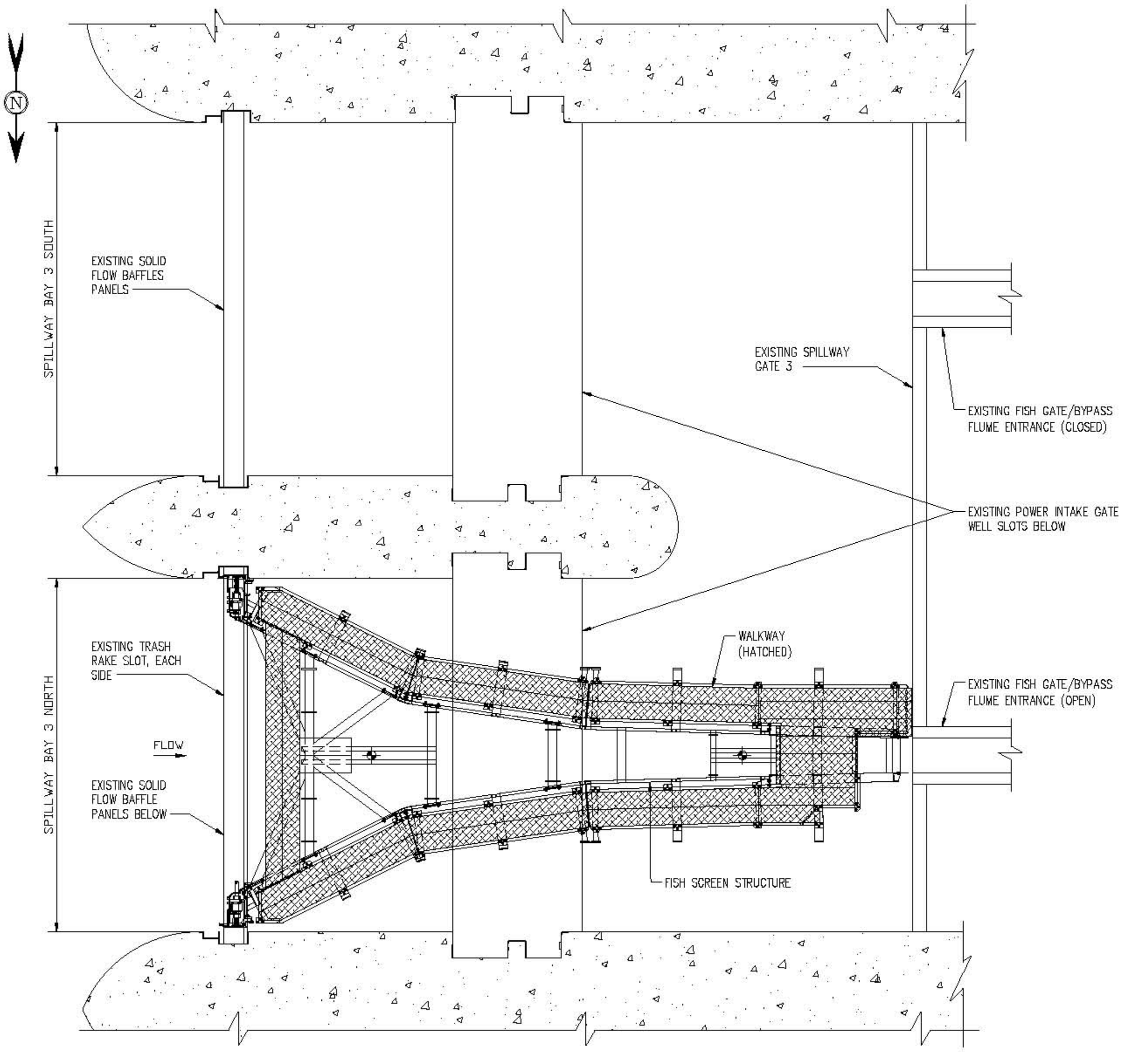


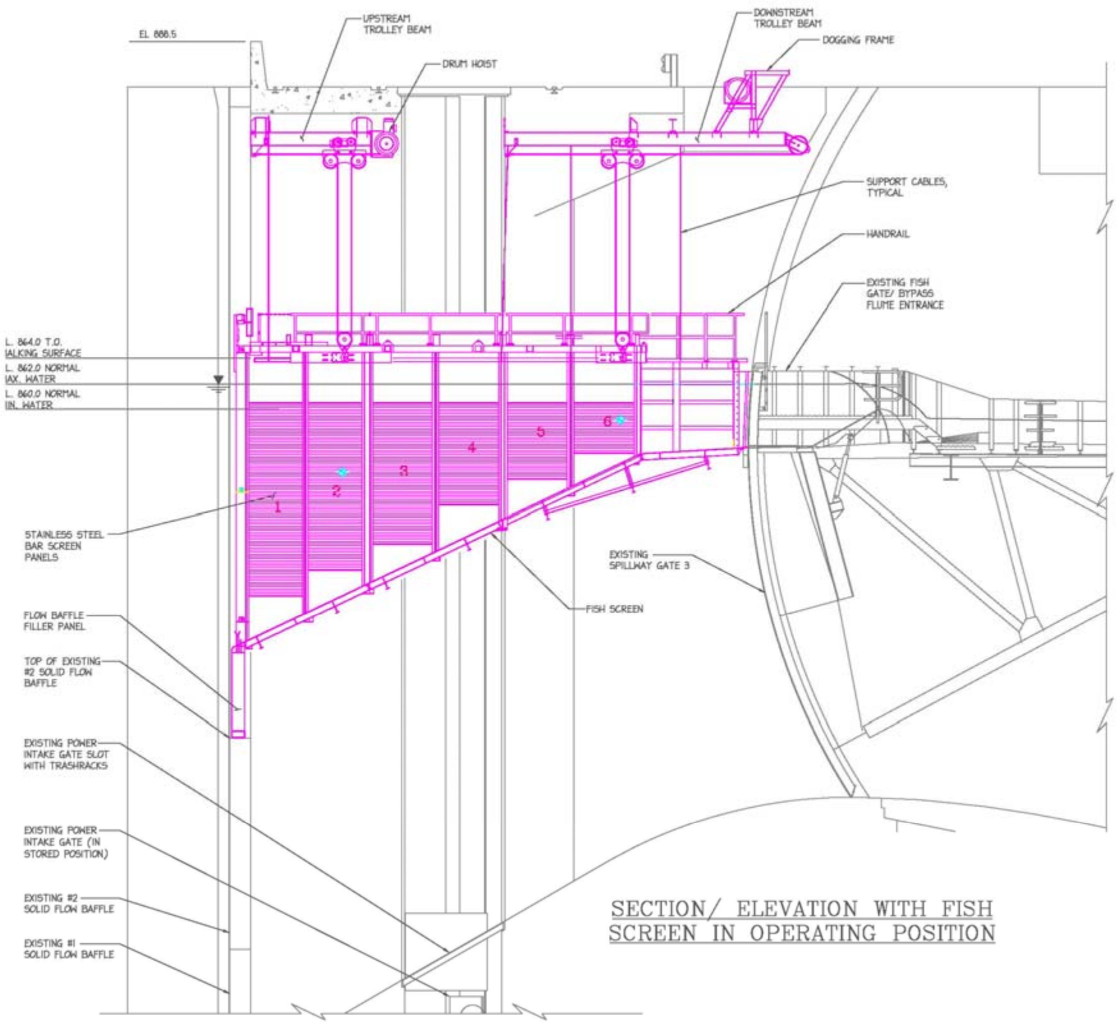
COWLITZ FALLS PROJECT DAM PLAN
FIGURE 4-1

3) *Forebay bathymetry*



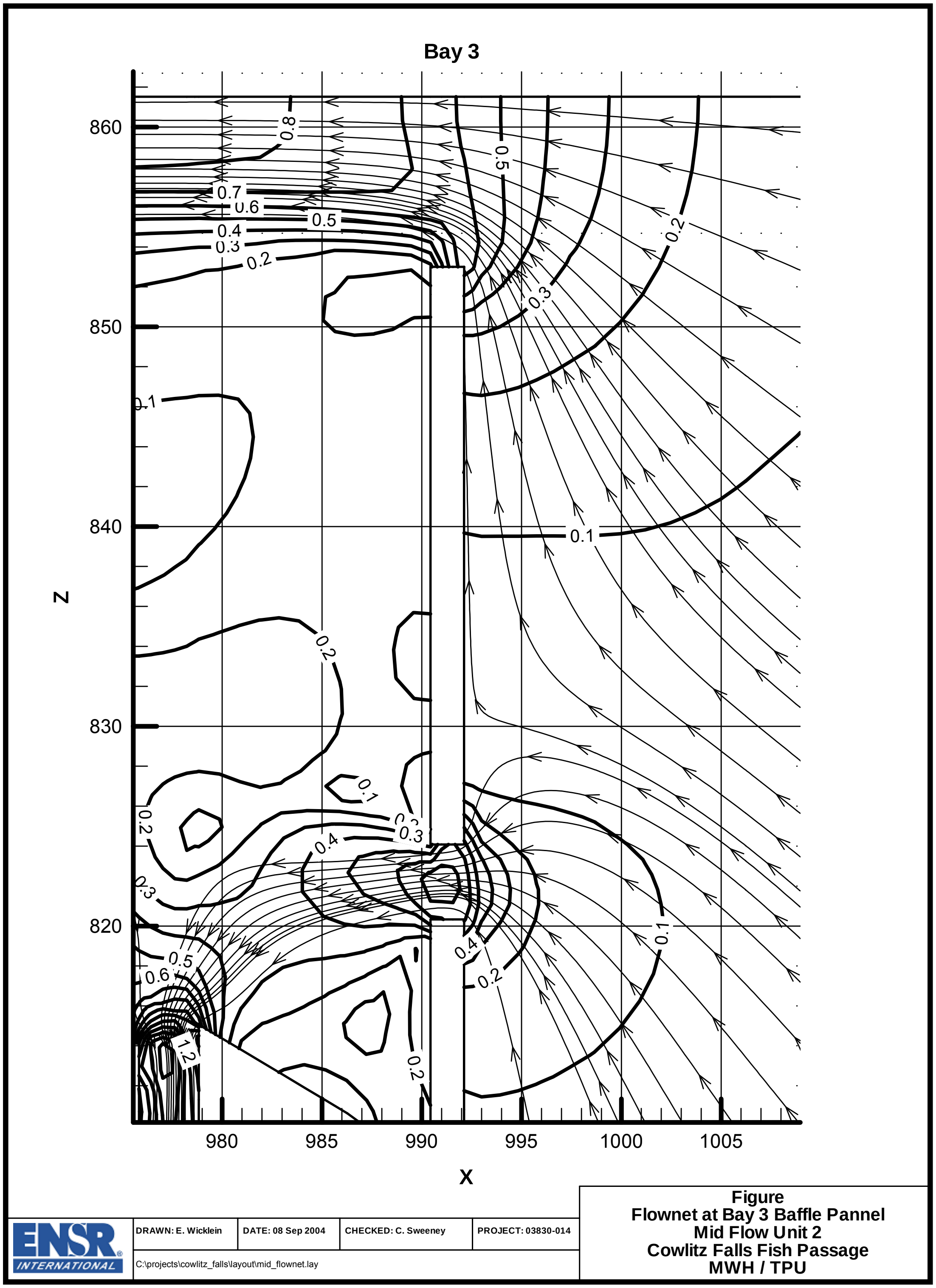
4) *Current plan and profile of the SFO structure*

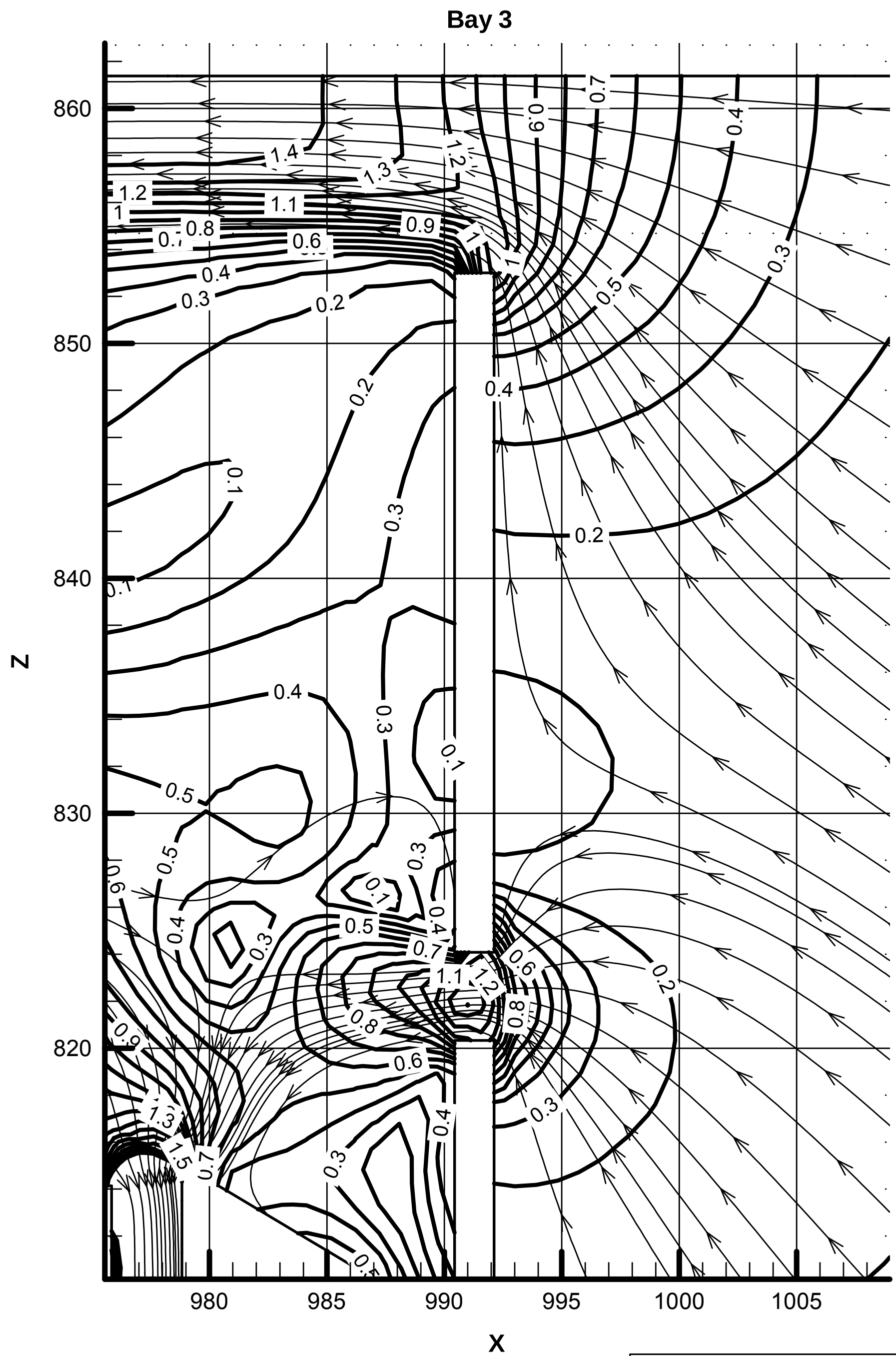




SECTION/ ELEVATION WITH FISH SCREEN IN OPERATING POSITION

5) *Forebay flow field*





DRAWN: E. Wicklein	DATE: 08 Sep 2004	CHECKED: C. Sweeney	PROJECT: 03830-014
C:\projects\cowlitz_falls\layout\high_flownet.lay			

Figure
Flownet at Bay 3 Baffle Pannel
At High Flow Unit 2
Cowlitz Falls Fish Passage
MWH / TPU

Project Description

Project: Upper Baker River Surface Collector

Presenter: *Nick Verretto, PSE*

Completed By: Nick Verretto
Email: nick.verretto@pse.com
Phone: 425-462-3441
Date: 14 January 2007

A) Introduction

The Baker River Hydroelectric Project (FERC No. 2150) consists of two dams and reservoirs, with a floating surface collector located in each forebay. The reservoirs are created by the Upper and Lower Baker dams, impounding Baker Lake and Lake Shannon (alternatively, Upper Baker and Lower Baker Lakes).

1) *Why was SFO considered?*
    - Relicensing of the Baker River Project was initiated May 2000, impelled by the original license expiration April 2006. Review of all passage alternatives for replacement of existing facilities was initiated at this time. An exhaustive selection process determined that the floating surface collector (FSC) was most applicable for the Project. Further, a broad variety of migration studies over a 20-year period indicated system success, the FSC could be easily modified in-field to reflect future decisions, past experience contributed to confidence, and a variety of other factors. Start-up of the new FSC, with inlet flow capacities of 500 and 1000 cfs, or 10-20% of the plant hydraulic capacity, is scheduled March 2008. Fabrication is in process, and construction begins February 2007.
    - The new FSC will replace the existing “gulper” (also an FSC) but with increased flow, criteria screens and improved hydraulics.
    - The existing FSCs, located in forebays of both reservoirs, were installed at original license issuance, Lower Baker (LB) April 1958, and Upper Baker (UB) April 1960. Although initial confidence in the facilities waned during the late 1970s and early 1980s due to declining sockeye numbers, subsequent success of the past 20-year fish passage improvement program in remedying the decline contributed to confidence in the FSC concept, particularly in the deep water reservoirs where few viable passage options exist.
2) *What initial data kick-started the process?*
    - Testing of spill through gates was conducted earlier at Lower Baker, 1952-1953, with survival rates of 36% sockeye and 46% coho, while survival through units was 66% sockeye and 72% coho.
    - Testing of spill through a 500 to 600-cfs ski-jump spillway was conducted earlier at Lower Baker, 1955-1957, with a combined survival of 85% versus 40% through unmodified spill gates. This was ultimately rejected due to lost generation and loss of pool control.
    - Initial gulper prototype development and testing was performed at Mud Mtn. Dam, ~ 1955-1956.
    - Lower Baker gulper was installed April 1958, and has been in continuous operation.
    - Upper Baker gulper was installed April 1960, with long-term mark-recapture studies indicating over 55% survival.
    - Migration studies at Upper Baker using two- and three-dimensional tracking indicated coho and sockeye migrated primarily in the upper water column and were finding the entrance to the gulper, although many rejected at the entrance.
    - Gulper improvements made through an iterative modifications process, including the addition and refinement of exclusionary barrier nets, resulted in continuous increases in collection effectiveness.
3) *What SFOs were investigated?*
   Surface collection alternatives considered were analyzed based on adherence to 40 criteria, and included:
    - FSC
    - Floating conventional screens

- Floating high speed screens, or modular inclined screens (MIS) on tower
- Spill

The criteria fell into six general categories:

- Fish Capture
- Fish Injury / Survival
- Constructability
- Operability
- Maintainability
- Adaptability
- Cost

The Alternative Selection Process consisted of the following steps:

- Brainstorming
- Affinitization reduced alternatives to 25
- Filter matrix & fatal flaw analysis reduced alternatives from 25 to 19
- Expert Choice reduced alternatives from 19 to 2
- Settlement reached

The terms of the Settlement Agreement, reached November 2005, prescribed:

- Floating surface collection & nets
- Adaptive management approach
- 500 cfs to 1000 cfs pumped flow
- Early implementation

FSC Modeling & Pump Diffuser Design Objectives

- Positive sweeping flow along net
- Converging & rising flows to entrance
- Positive normal flow at entrance
- Minimize pump discharge bed impact velocities (< 0.3 fps at 1,000 cfs at low pool)
- Minimize effects on FSC operation & reliability

Surface collection alternatives modeled or prototyped included:
Historical:

- Testing of spill through unmodified gates and through a ski-jump spillway was conducted earlier at Lower Baker, 1952-1953 and 1955-1957.
- The existing gulpers -- crude prototypes of a modern FSC – have been in operation for over 40 years.

Recent:

- The newly designed FSC was modeled twice using computational fluid dynamics (CFD) and once with a 1:10.43 scale physical model. Additionally, the forebay (approach) conditions were modeled twice using CFD for siting and design considerations. Montgomery Watson Harza and Washington Group International were the lead design engineering firms, and ENSR developed and performed the physical and CFD modeling 2004-2006.

B) Project History and Path to Final Design of SFO: Floating Surface Collector

History of development, testing and improvements.

- 1925 – Lower Baker dam completed. Upstream passage provided, but downstream passage was through gates or penstock only.
- 1952-53 – Testing spill through gates vs. entrainment through units conducted at Lower Baker.
- 1954 – Project mitigation research initiated.
- 1955 – Construction of Upper Baker dam initiated.
- 1955-57 – Testing of spill through a ski-jump spillway conducted at Lower Baker. 1955 – Ski-Jump
- ~1955-56 – Initial gulper prototype development and testing at Mud Mtn. Dam.
- 1958 – Lower Baker gulper installed April, 36’ x 68’, 90-cfs flow, bypass pipeline to tailrace, tested two years before designing Upper Baker gulper, modified for buoyancy and stability (scheduled for replacement March 2012).
- 1959 – Upper Baker dam completed.

- 1960 – Upper Baker gulper installed April, 36' x 70', increased flow to 165 cfs, opposing pumps discharge, bypass pipeline to tailrace (scheduled for replacement March 2008).
- 1978 – Juvenile outmigration studies initiated in response to declining salmon returns.
- 1981 – Run restoration efforts begins
- 1984-present – Mark-release-recapture studies conducted for system performance information.
- Baker River Committee (ad-hoc team of co-managers -- agencies, tribes -- and PSE) formed 1985
- 1986-92 – Forebay locations of both gulpers tested to improve attraction flow relative to intakes.
- 1986-2002 – Net pen program for interim recovery.
- 1986-2004 – Forebay barrier nets installed and refined, from 2" x 100' deep to ¼" x full depth (up to 285' deep).
- 1987 – Trap-and-haul initiated at Upper Baker.
- 1987-89 – Forebay trap-and-haul initiated for system performance information.
- 1988 – Trap modifications increase gulper flow.
- 1990s – Declining sockeye and coho runs reversed.
- 2000-03 – Intensive fish passage alternatives conceptual engineering and review under formal relicensing process.
- 2000 – Gulper intake pump cycling tested for increased attraction.
- 2001 – Surface attraction flow induced and tested through intake modification.
- 2002 – Outmigrant tracking using radio telemetry and 3-D acoustics performed under various operating conditions.
- 2003 – FSC selected as preferred alternative for downstream passage system, scheduled for early implementation, March 2008. Design development initiated immediately with MWH.
- 2003-04 – Guide nets and net transition structure installed as interim measure, and to test modified entrance conditions and improved hydraulics.
- 2004-05 – ENSR conducts physical modeling of entrance, primary and secondary screens, using 1:10.43-scale prototype.
- 2004-05 – ENSR conducts CFD modeling of forebay flow and FSC discharge conditions.
- 2005 – Relicensing settlement signed, license issuance anticipated 2007.
- 2005-06 – ENSR conducts second CFD modeling of forebay flow and FSC discharge conditions. Additional CFD modeling includes primary & secondary screens, and approach and discharge conditions of submersible pumps.
- 2006 – Fabrication of new FSC initiated, scheduled for startup March 2008.

C) Present Status of Facility

Project layout/bypass system configuration.

- The existing Upper Baker surface collector was installed 1960. Modifications/improvements made to the Upper Baker surface collector include: 1986 – addition of barrier nets, 1987 – addition of bypass trap and replacement of pipeline bypass system with truck transport, 1992 – gulper moved from right bank to point centered on intakes, 1996 – installation of upgraded trap, 2004 redesign of barrier net, construction of net transition structure (NTS) which modified entrance conditions, and removal of fish baffle (which diverted penstock intake water to depth of more than 100').
- The existing Lower Baker surface collector was installed 1958, and is scheduled for replacement March 2012. Modifications/improvements made to the Lower Baker surface collector include: 1986 – addition of barrier nets and relocation of gulper 1200' upstream of dam, 1989 – addition of bypass trap, 1997 – truck transport replaces bypass pipeline. Replacement with a new FSC is scheduled March 2012.

D) Future Plans

Project layout/bypass system configuration.

- The future Upper Baker FSC is scheduled for startup March 2008. The FSC, with criteria screens for 500-cfs inflow, but capable of a pumped-flow capacity of 1000 cfs, will be located in front of and 150' upstream of the penstock intakes. Fish entering the forebay will first encounter the guide net, then the NTS. The net is full depth (285') and consists of ¼" nylon mesh, but for the 3/32" mesh at the top

30'. The NTS gradually transitions from 50' deep at its entrance to 16' at the entrance to the to the primary screens channel. The NTS is 75' wide at its entrance and 16' wide at the entrance to the to the primary screens channel. Acceleration is gradually increased from 0.05 to 2.0 fps/ft, with no deceleration occurring prior to capture. The capture velocity of 7.5 fps is maintained for approximately 10 feet in the secondary screens channel. Discharge into the holding area of 3 cfs occurs at 5 fps. The pumped-flow capacity is achieved through four submersible primary screen pumps, and four submersible secondaries. Both primaries and secondaries discharge into their own common plenums, which then distribute and discharge the flow horizontally through a number of gates. Other key features of the net FSC include:

- Modular design for future modifications, e.g., reduced acceleration, increased flow with criteria screens, increased capture velocity
- Pontoons to minimize buoyancy excursions.
- Improved operational adjustability.
- Belly tanks for complete dewatering for ease of maintenance, modifications, studies, and winter lay-up.
- Variable speed pumps - adjustable attraction flow, proven design, easier maintenance
- Optimized primaries for reduce exposure time
- Subcritical open-channel flow throughout.

2) *Modeling and prototype development.*
   - 2003-04 – Guide nets and net transition structure installed as interim measure, and to test modified entrance conditions and improved hydraulics.
   - 2004-05 – ENSR conducts physical modeling of entrance, primary and secondary screens, using 1:10.43-scale prototype.
   - 2004-05 – ENSR conducts CFD modeling of forebay flow and FSC discharge conditions.
   - 2005 – Relicensing settlement signed, license issuance anticipated 2007.
   - 2005-06 – ENSR conducts second CFD modeling of forebay flow and FSC discharge conditions. Additional CFD modeling includes primary & secondary screens, and approach and discharge conditions of submersible pumps.
3) *Cost.*
   - Construction cost – approx. $20 million.
   - Evaluation cost – approx. $250 annually.
4) *Biological performance.*
   - Existing surface collector recapture rates in mark-release-recapture studies over the 23-year period of record indicate a FCE of approximately 55%. Criteria for the new facility are 95% juvenile collection, 98% transport and holding, 80% reservoir passage & survival and 75% through these combined.
5) *Potential future modifications and/or testing.*
   - Testing of oscillating or pulsed flow.
   - Testing of turbulence-creating devices in forebay and NTS.
   - Potential to modify FSC to increase flow to 1000 cfs, with insertion of additional screening module for adherence to criteria.
   - Insertion of modular section to allow reduction in acceleration.
   - Insertion of modular section to increase capture area width.
   - Diagnostic testing at potential rejection points.

E) Conclusions and lessons learned

Guiding principles/recipes for success.

- Collect hydraulic and bathymetric information early in process.
- Collect biological information early in process, particularly 2-D and 3-D tracking information.
- Design for future adaptability.
- Incorporate value engineering (VE) into process early.
- Involve contractors early in design development.

- Partnerships & trust pay dividends – be committed to building long-term relationships and partnerships.
- Fully vet all guidelines & criteria.
- Hydraulic and physical modeling are an invaluable contribution to design development and troubleshooting.
- Nets are key to Baker success.
- Initial estimates must be conservative.
- Commit yourself to an iterative process of continual change and improvement – there are no "silver bullets".

F) Exhibits

1) *Aerial photo*

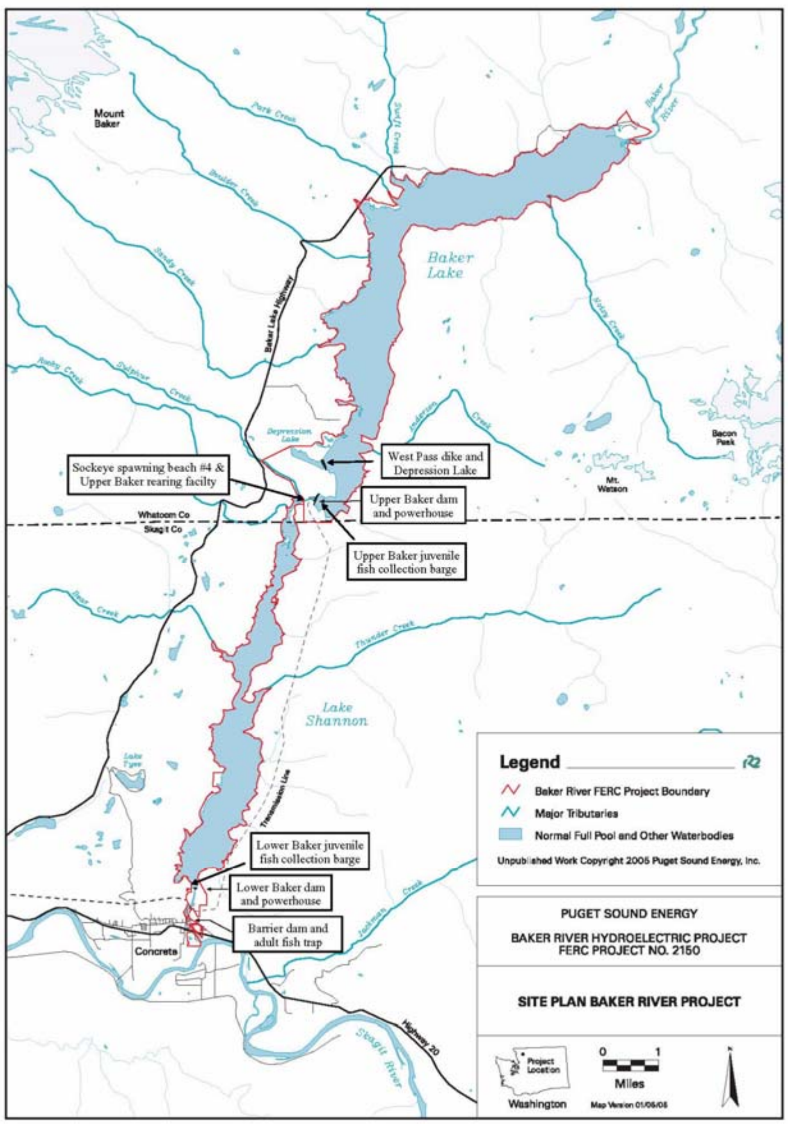


Figure 1. Baker River Project site plan.

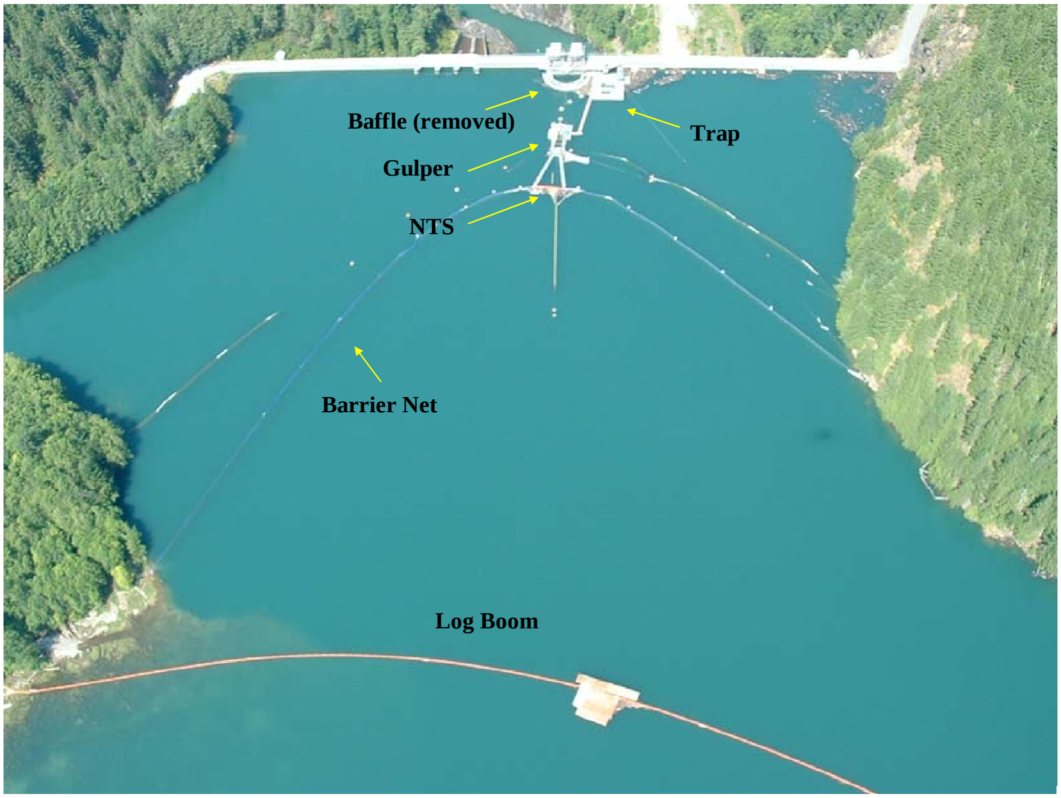


Figure 2. Upper Baker forebay aerial showing existing surface collector, NTS, net and trap.

Figure 3. Lower Baker forebay aerial showing existing surface collector, net, trap, and defunct pens.

Figure 4. Upper Baker forebay aerial showing rendering of future FSC, NTS and net.

Figure 5. Rendering of future Upper Baker FSC.

2) *Current project layout with SFO*

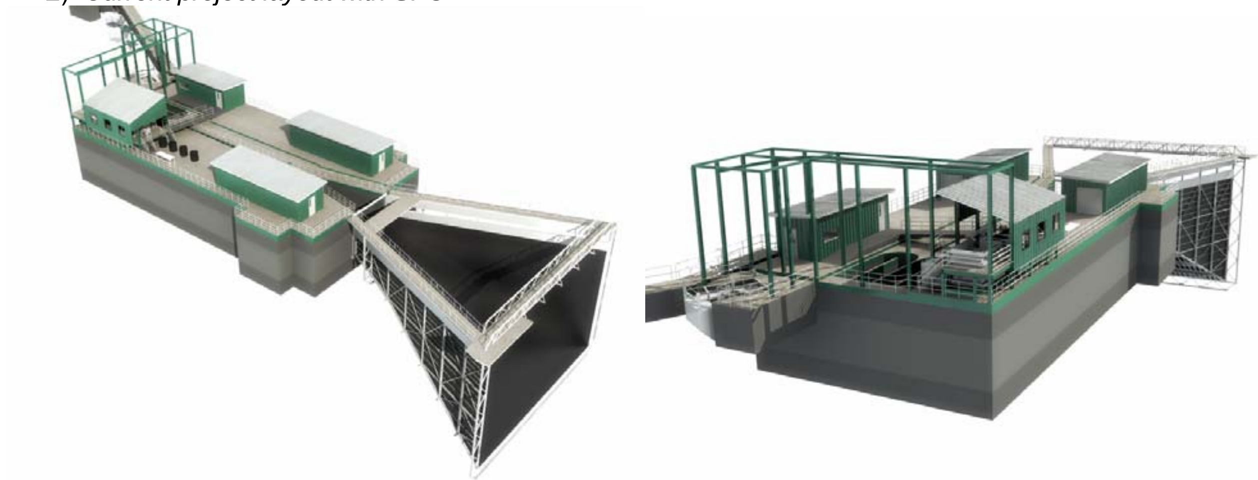


Figure 6. Renderings of future Upper Baker FSC

3) *Forebay and tailrace bathymetry*

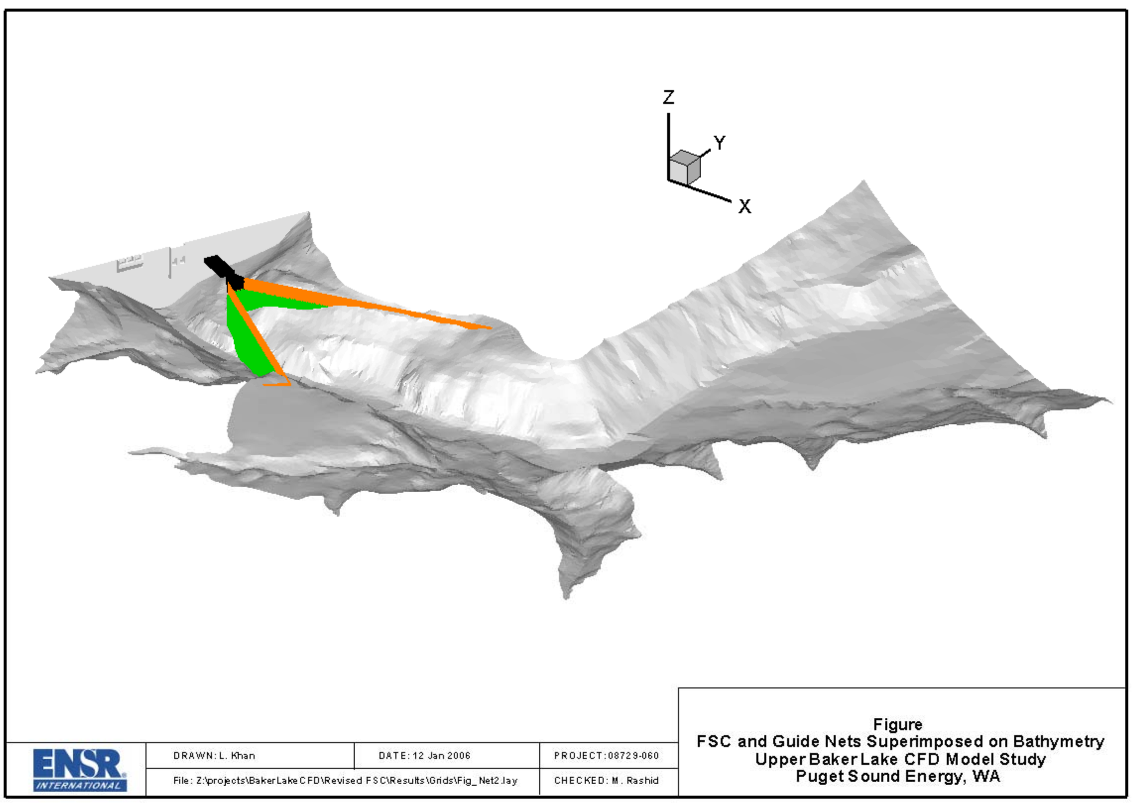


Figure 7. Upper Baker forebay bathymetry with net, FSC and dam (ENSR CFD model, 2005).

4) *Current plan and profile of the SFO structure*

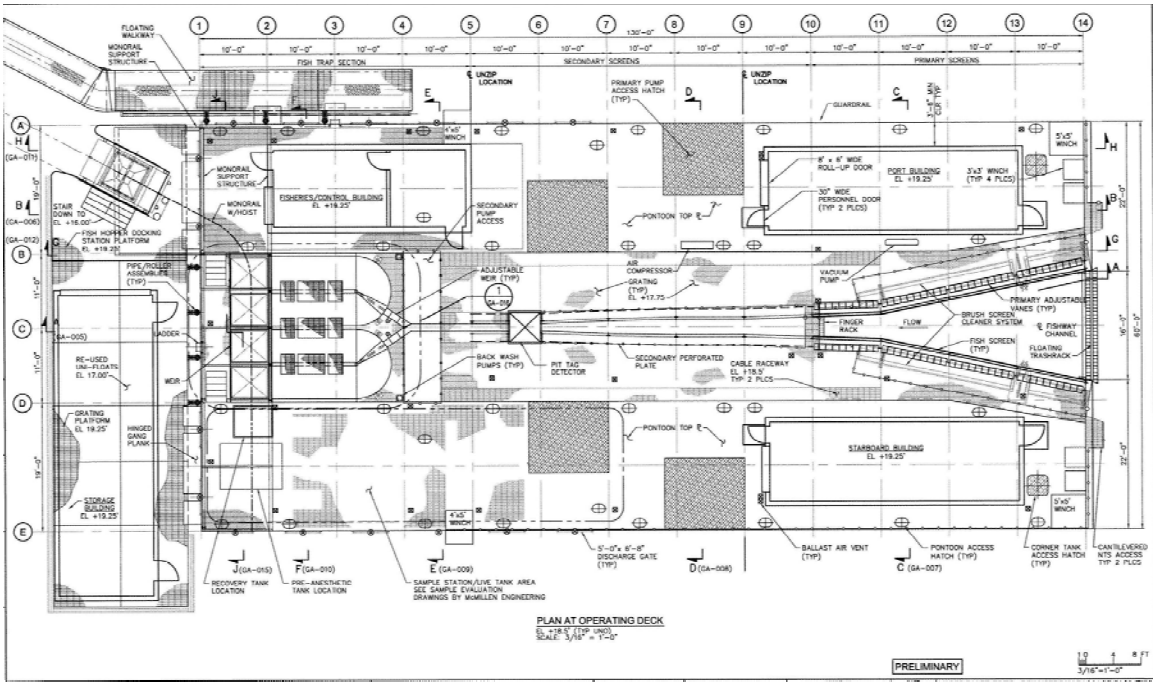
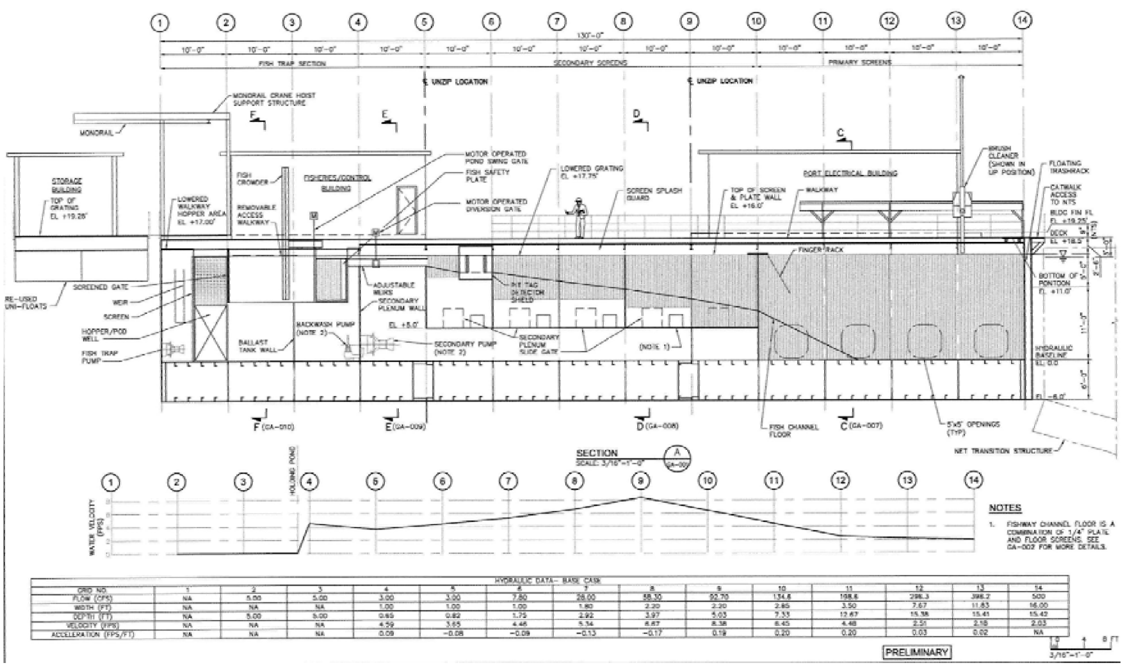


Figure 8. Plan view of future Upper Baker FSC.



HYDRAULIC DATA– BASE CASE														
GRID NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FLOW (CFS)	NA	5.00	5.00	3.00	3.00	7.80	28.00	58.30	92.70	134.8	198.6	298.3	398.2	500
WIDTH (FT)	NA	NA	NA	1.00	1.00	1.00	1.80	2.20	2.20	2.85	3.50	7.67	11.83	16.00
DEPTH (FT)	NA	5.00	5.00	0.65	0.82	1.75	2.92	3.97	5.03	7.33	12.67	15.38	15.41	15.42
VELOCITY (FPS)	NA	NA	NA	4.59	3.65	4.46	5.34	6.67	8.38	6.45	4.48	2.51	2.18	2.03
ACCELERATION (FPS/FT)	NA	NA	NA	0.09	−0.08	−0.09	−0.13	−0.17	0.19	0.20	0.20	0.03	0.02	NA

Figure 9. Elevation view and hydraulic grade line of future Upper Baker FSC

5) Forebay & tailrace flow fields

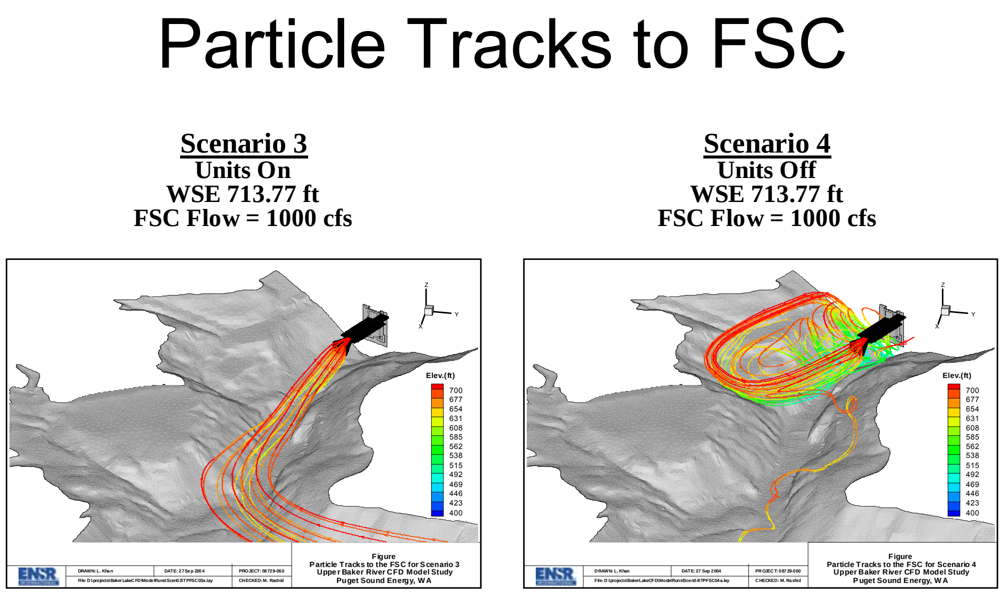


Figure 10. Upper Baker forebay particle tracking to FSC (ENSR CFD model, 2005).

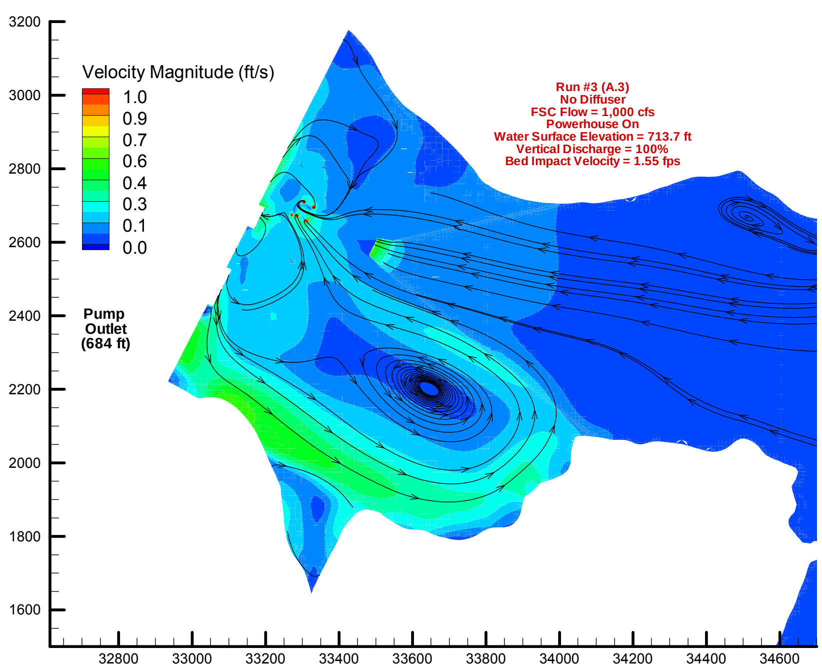


Figure 11. Upper Baker forebay flow net & FSC approach pattern (ENSR CFD model, 2005).

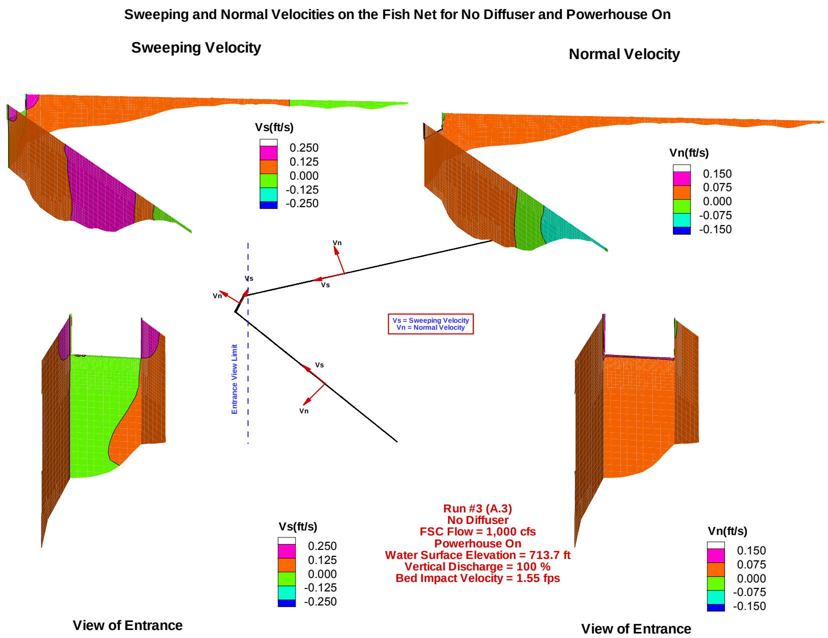
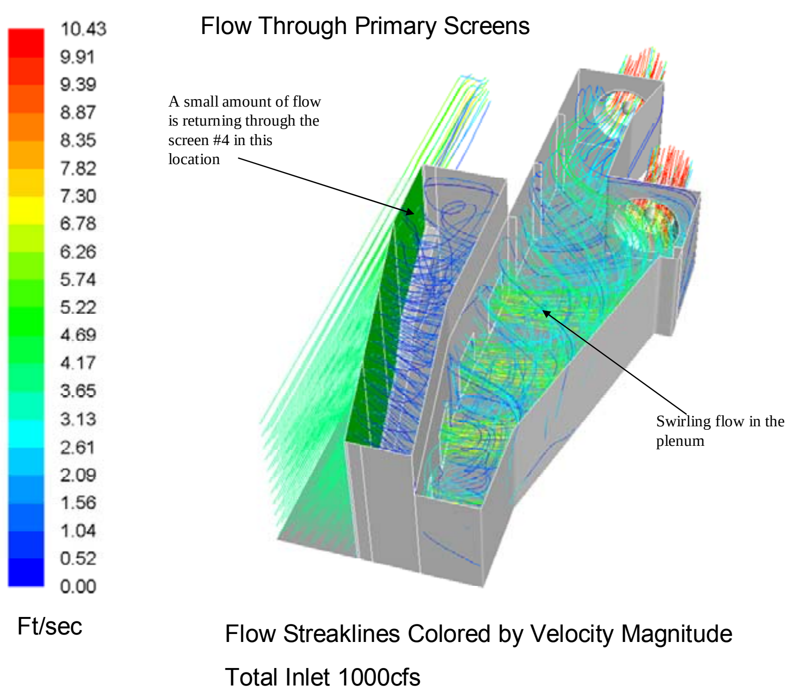
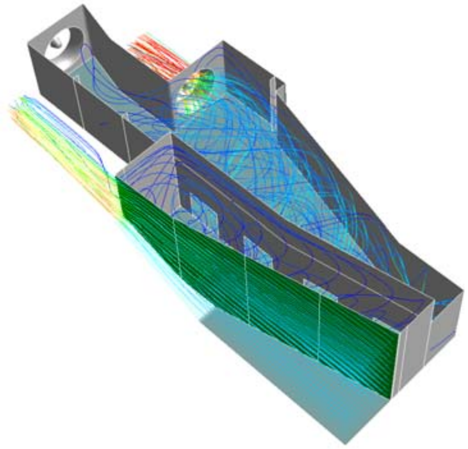
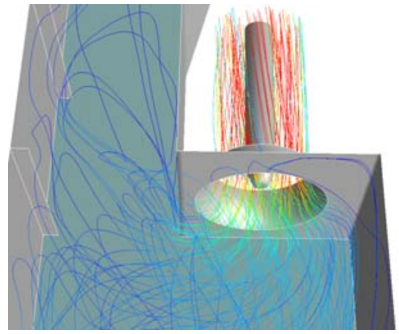


Figure 12. Upper Baker forebay guide net sweeping and normal flow pattern (ENSR CFD model, 2005).







pump	dP	swirl	dev. axial	ang. mom.	prop torque	ang. mom. ratio
	ft H2O	degrees	percent	Nm	Nm	percent
outboard	0.329	9.36	-11.8 to 6.1	1351	3403	39.70
inboard	off	off	off	off	off	off

Pump Approach Flow

Total Inlet 500cfs Outboard Pump on

Figures 13 & 14. Upper Baker FSC primary screens and pumps approach conditions (ENSR, 2006).

Project Description

Project: Round Butte Surface Bypass

Presenter: ***Don Ratliff (PGE)***

Completed By: Don Ratliff

Email: don.ratliff@pgn.com

Phone: 541-475-1338

Date:______________________________

A) Introduction:

1) *Why was SFO considered?*
   - The SFO was considered as part of a relicensing package to renew fish passage upstream of Round Butte Dam as major fisheries mitigation measure in conjunction with an anadromous fish reintroduction program?
     - The objective was to renew fish passage for anadromous and resident fish species
     - Downstream Fish Passage at Lake Billy Chinook had proven unsuccessful because of the deep intake at Round Butte Dam, and surface currents that did not come to the Dam and original downstream fish-collection facility.
     - A surface outlet was considered as a possibility to draw downstream migrants to the collection facility during the primary smolt migration period, February through July.
2) *What initial data kick-started the process?*
   - Initial temperature and hydrodynamic modeling suggested that surface water could be withdrawn from Lake Billy Chinook, at least through May, without violating water temperature standards for the lower Deschutes River.
3) *What SFOs were investigated (model or prototype)?*
   - Surface Collector

Complete the following for the latest SFO identified in A.3.

B) SFO Alternative 1 (path to final design or current SFO alternative): Surface Collector

1) *What modeling and prototype development was done? Present in timeline format*.
   - Began modeling in early 1996. Numerical Model efforts have included:
   - 1. SNTEMP Model for effects of the Pelton Round Butte Project on temperatures in the Lower Deschutes River.
   - 2. Box-Exchange, Transport, Temperature, and Ecology of a Reservoir (BETTER) Model to initially predict temperature changes in Lake Billy Chinook associated with surface withdrawal.
   - 3.1995: Environmental Fluid Dynamic Code (EFDC) -3D hydrodynamic numerical model of Lake Billy Chinook.
   - 4. CE-Qual-W2 (2-D, vertical water quality model of Lake Simtustus)
   - 5. RMA 10, 1-D mixed, hydrodynamic model for the lower Deschutes River.
   - 6. RMA 11, 1-D mixed, water quality model for the lower Deschutes River
   - In addition, PGE looked at the use of a Computational Fluid Dynamics model of the forebay of Lake Billy Chinook, but decided not to use it due to the size of the area involved and problems with boundary conditions.
   - Instead, for near field predictive model, we increased the density of the EFDC model in the forebay where the new SWW tower was to be constructed.
2) *History of development and testing with the decision path*.
   - Hydraulic evaluations included:
     - Two Physical Models have been constructed to aid design:
       - A model of the tertiary screen dewatering zone, large fish separator and down well.
       - A model of the Selective Water Withdrawal Structure with separate tanks for the Surface Water Withdrawal Structure and the Bottom Withdrawal Structure.
     - In addition, PGE has done physical current studies of Lake Billy Chinook including:

  - o Studies with drogues under current normal conditions and studies using spill to simulate surface water withdrawal.
  - o Studies of the historic downstream collection system using dye to trace water movement.
  - o Studies using current flow measurement with Acoustic Doppler Current Profiler equipment to document present currents, and to calibrate and verify the EFDC Hydrodynamic Model.
- Biological evaluations included:
  - Screen Test Facility to study biofouling
    - o Testing performance of both circular and slotted perforations
    - o Testing performance of various paint coating systems
    - o Designed to operate at 0.8 fps normal to screen (smolt criteria)
  - Test of 20-inch Hidrostal Fish Pump at the Klamath A Canal for passing salmonids up to 15 inches

C) Present status of facility:

1) *Project layout/bypass system configuration: Surface Collector*
   - Will be at 50% design by the end of the year. A contractor has been designated and the materials and construction details are being worked on.
2) *Cost (Design, Construction, Evaluation)*
   - PGE is expecting the total cost to be ~60 million
3) *Biological performance*
   - The surface collector is in the development phase so there have been no biological performance studies.
4) *Future plans*
   - Development is 10 years and counting. Scheduled for construction in 2008 and start up in 2009.

D) Conclusions and lessons learned (from all designs):

1) *Data gaps identified*
   - 1. Anadromous fish migration behavior in low-velocity reservoir systems.
   - 2. Water velocity threshold targets trying to achieve at various point is the reservoir.

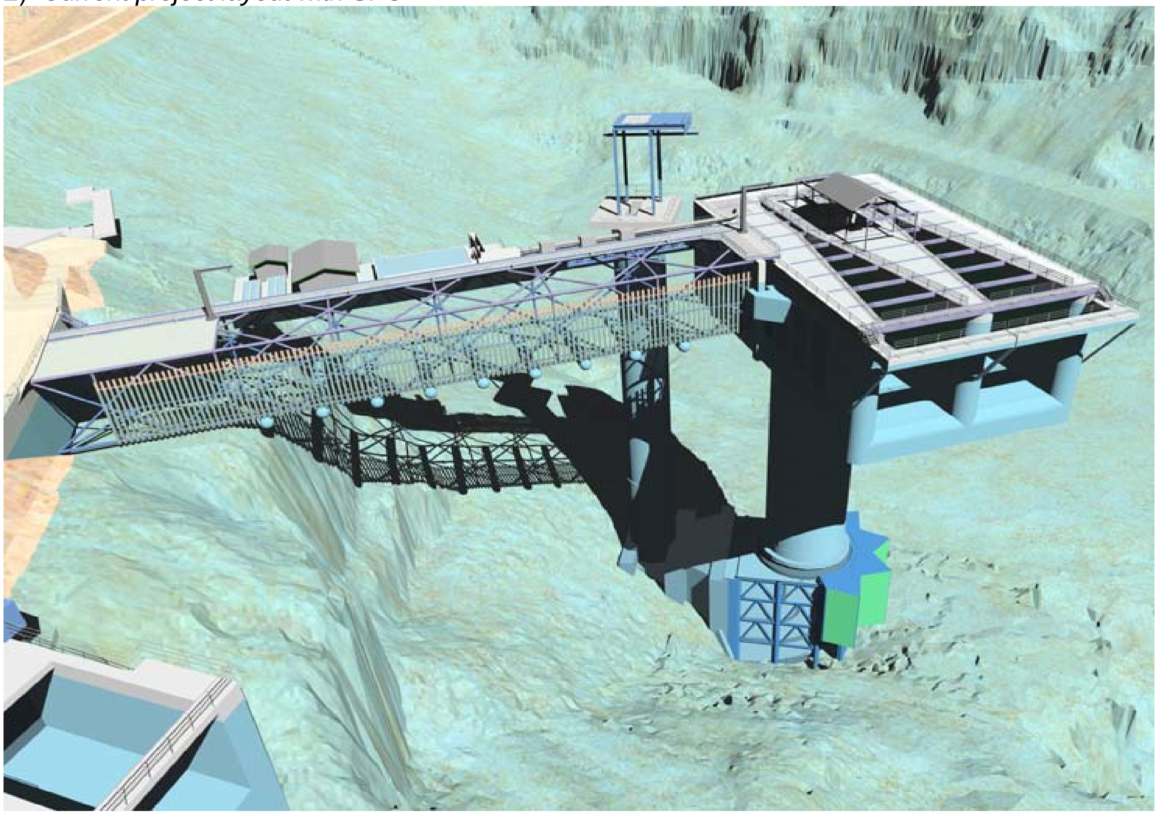
2) *Guiding principles/recipes for success*
   - 1. Communicate openly and honestly with all players.
   - 2. Create a team atmosphere with all interested parties so maximum brainpower focuses on solving problems and moving forward. Be certain the different disciplines are working closely with each other.
   - 3. Spend considerable time up front accumulating known information, defining the present situation, listing the unknowns, prioritizing the important remaining questions, and then developing a program to answer the questions.

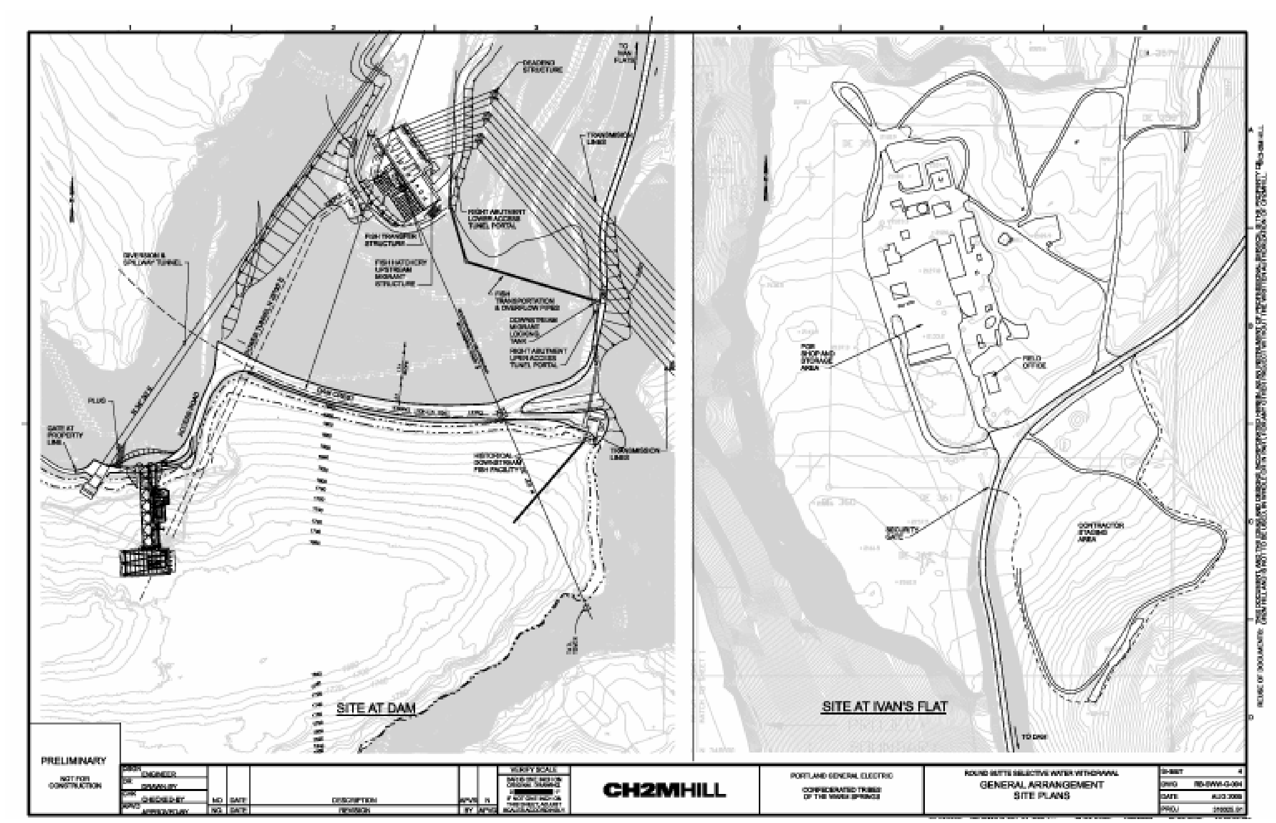
3) *Pit falls, i.e. what not to do*
   - Be certain to stay away from group mentality where people tend to think like other people, and not think for themselves. Be certain you have a diverse team, and everyone is encouraged to participate. Be certain to guide against situations that might pit one group against another.
4) *Absolute requirements*
   - Close working relationships with Tribal, Agency, and NGO representatives are extremely important.
   - An honest Value Engineering Effort is very worthwhile as it not only pushes everyone to reduce costs, it allows discussion of objectives and how best to meet them. In our case, it led to not only a more cost effective but also a much better design.
5) *If you had it to do all over again, what would you do differently?*
   - I would have worked harder to convince people that as much of the generation water as possible should be used to guide and capture downstream migrants. We got to that on the second alternative after the first exceeded budget restrictions. However, that should have been a criterion from the beginning.

E) Exhibits:

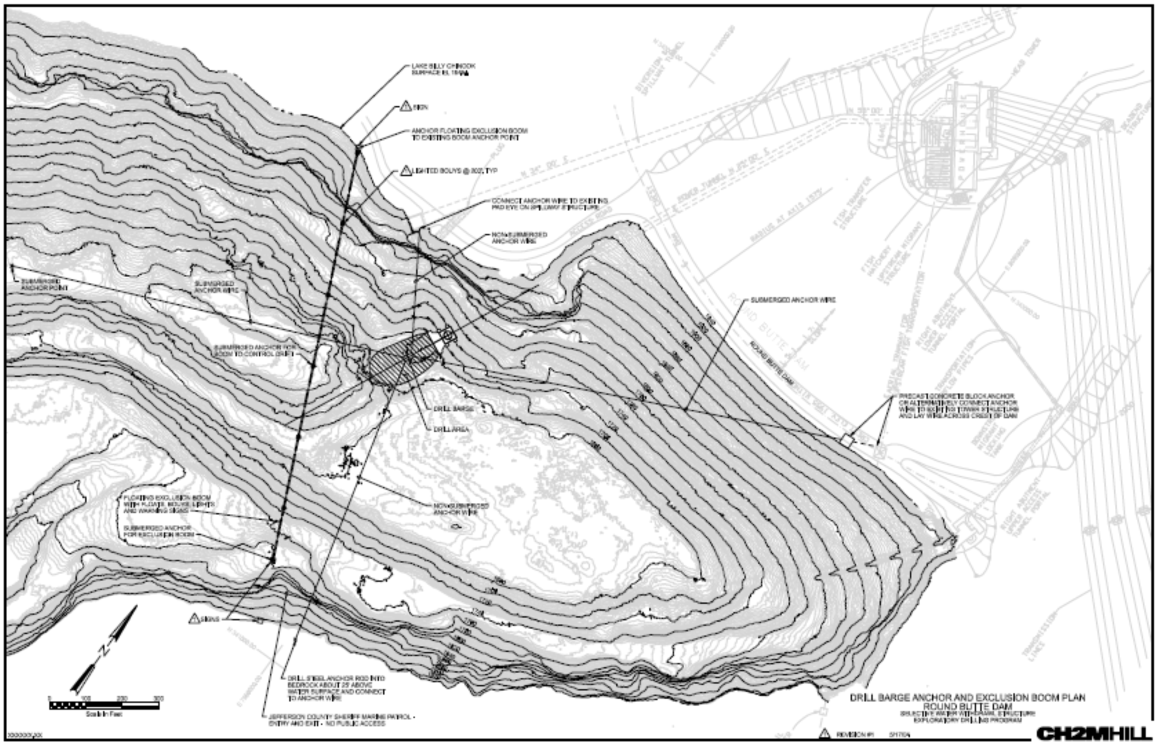
1) *Aerial photo*

2) *Current project layout with SFO*

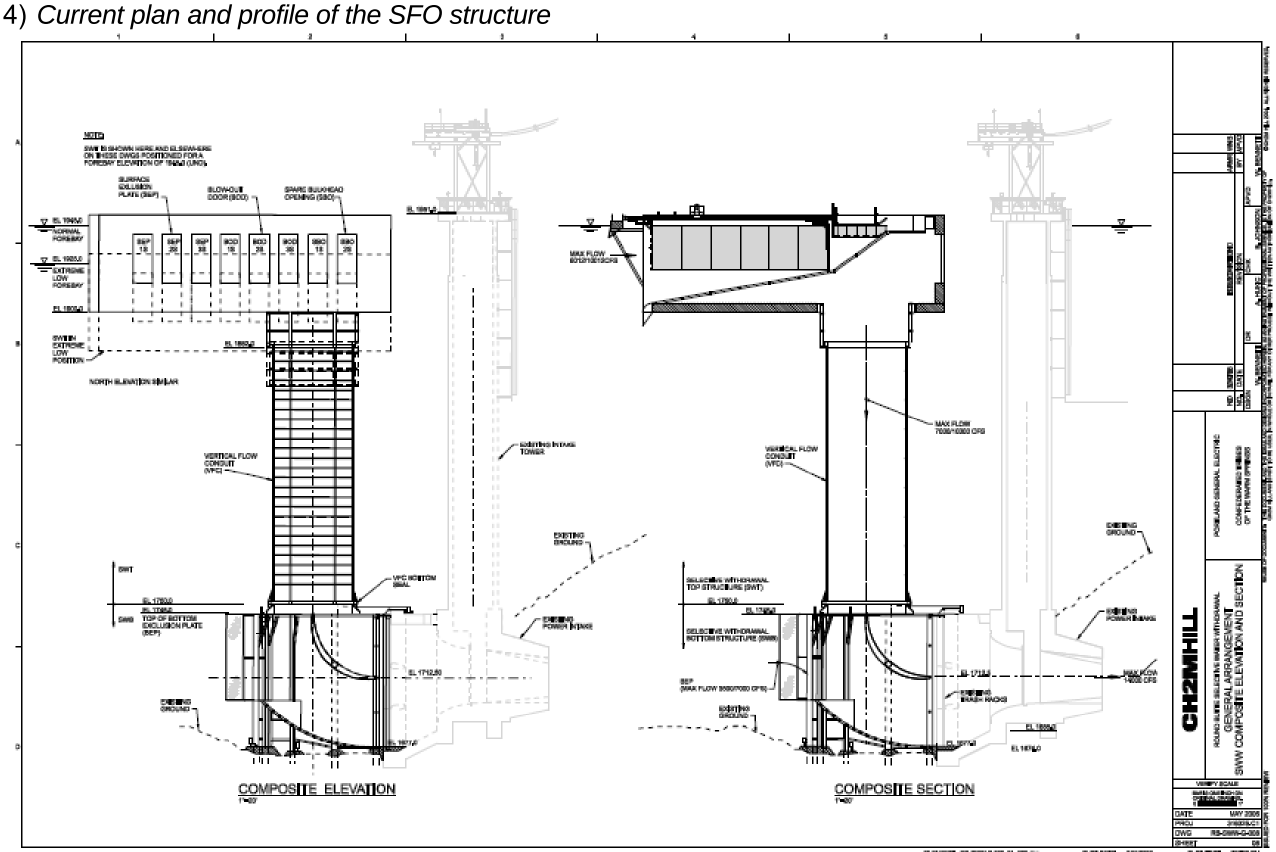


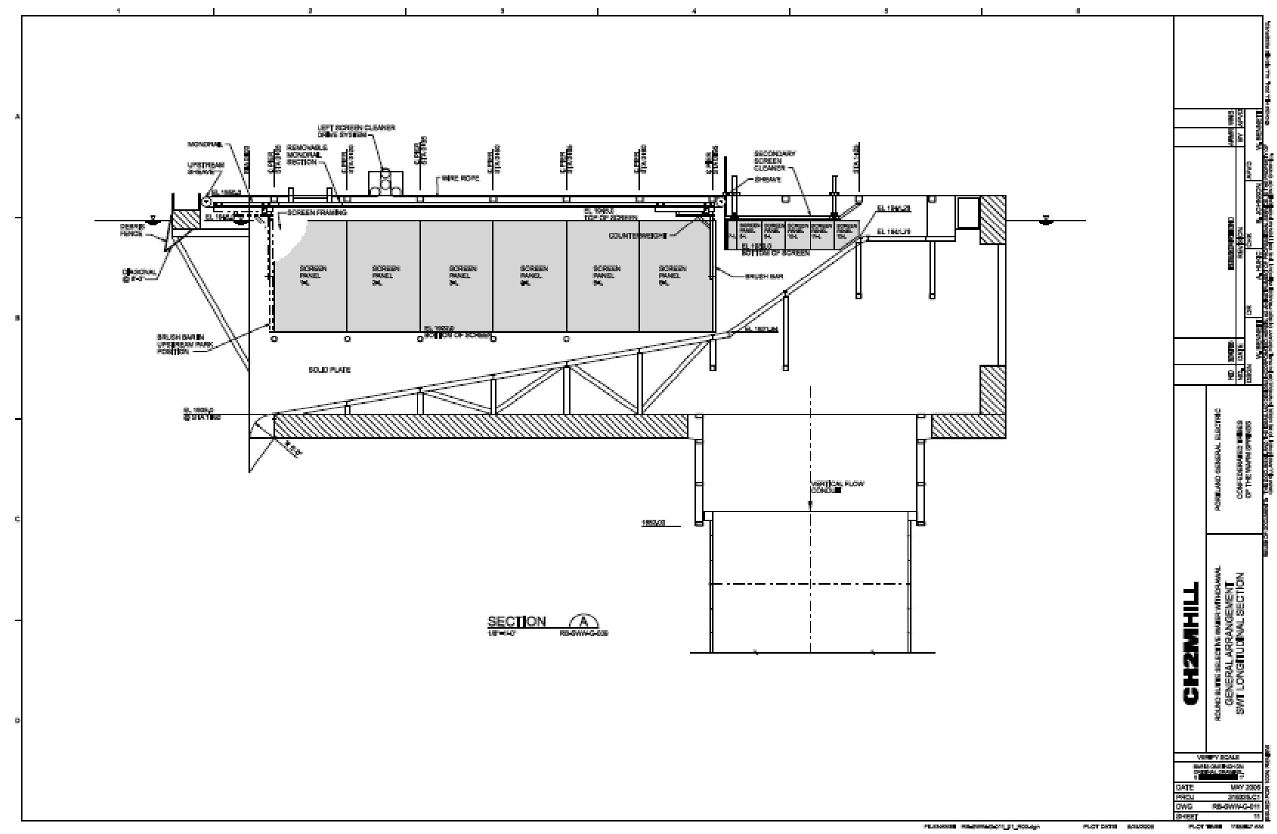


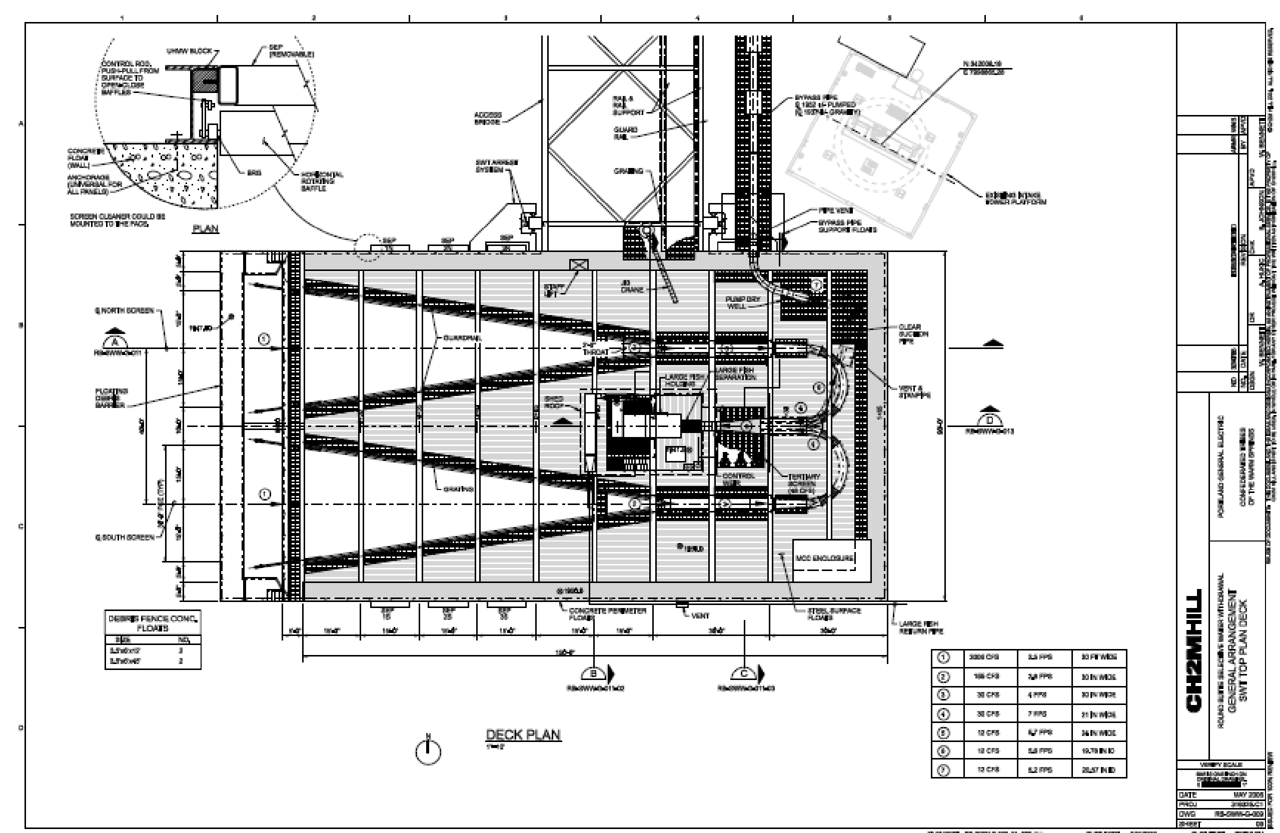
3) *Forebay and tailrace bathymetry*



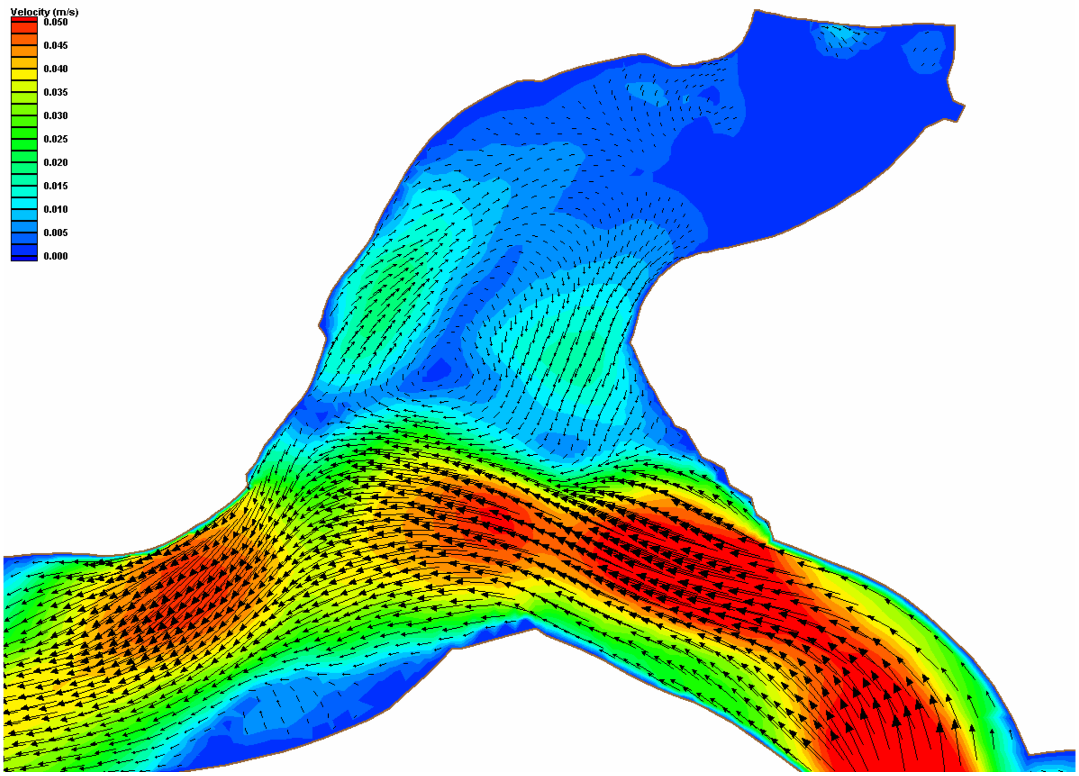
4) *Current plan and profile of the SFO structure*



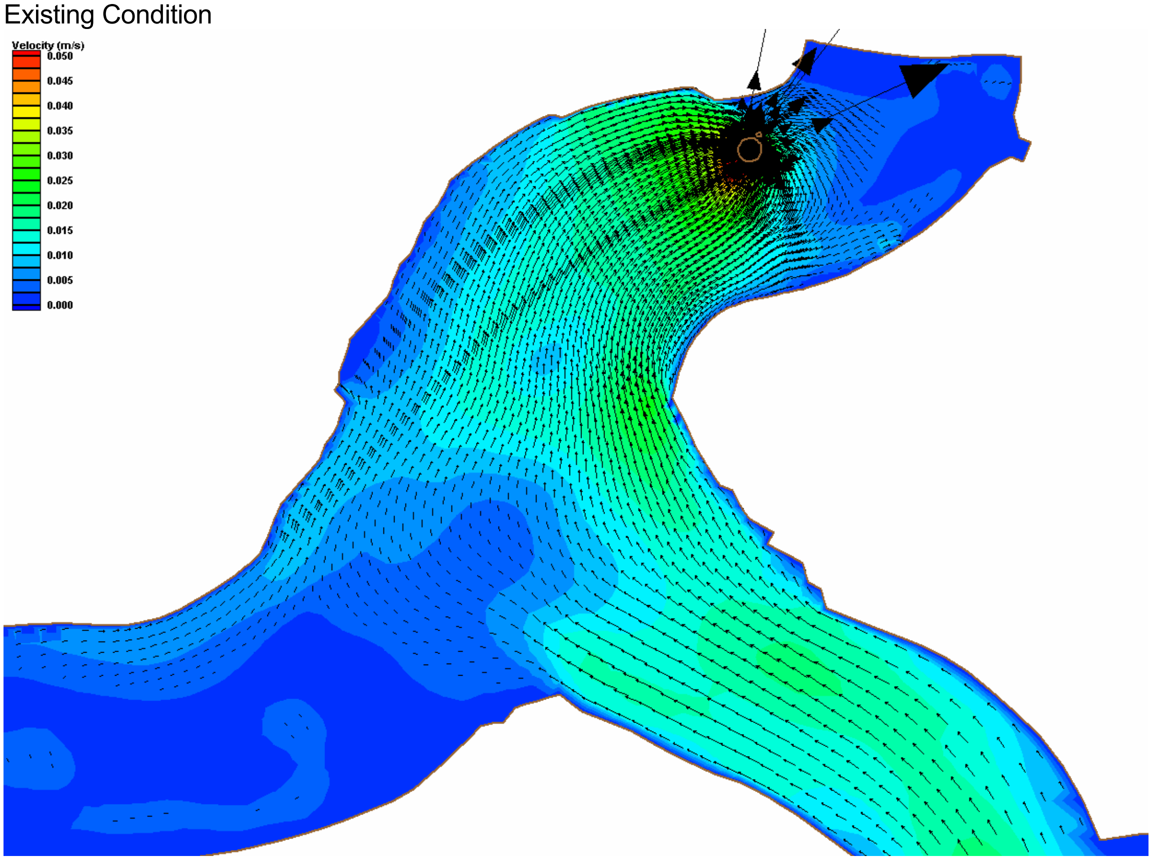

SECTION A
SCREEN PANEL
SOLID PLATE
COUNTERWEIGHT
CH2MHILL
GENERAL ARRANGEMENT
SWT LONGITUDINAL SECTION


PLAN
DECK PLAN
GUARDRAIL
GRATING
MCC ENCLOSURE
CH2MHILL
GENERAL ARRANGEMENT
SWT TOP PLAN DECK

5) *Forebay & tailrace flow fields*



Existing Condition



Predicted with SWW

Completed By: Doug Cramer

Email: doug.cramer@pgn.com

Phone: 503 630-8215

Date: 10/2/2006

Project Description

Project: North Fork and Rivermill Dams

Presenter: ***Doug Cramer (PGE)***

A) Introduction:

1) *Why was SFO considered?*
   - SFO was considered to improve smolt bypass as part of their relicensing agreement.
     - Each Facility
       - 99.5% survival for smolt
       - < 2 % injury to smolts
       - < 4 % injury to Fry
     - From North Fork to below River Mill
       - 97% Survival
       - < 2 % injury to smolts
       - < 4 % injury to Fry
       - Tiered Decision Structure for not meeting standards
2) *What initial data kick-started the process?*
   - Baseline Information
     - Flow Data
     - Reservoir Studies
     - Original Facility Evaluation
     - Fish Count Data
     - PIT Tag Studies
   - Relicensing Studies
     - Acoustic tags
     - Hydroacoustics
     - Radio telemetry
     - PIT Tag Studies
3) *What SFOs were investigated (model or prototype)?*
   - River Mill Dam: Obermeyer weir
   - North Fork Dam: Current surface collector (adult and juvenile fish passage facility-spill bay side)
   - North Fork Dam: Proposed future floating surface collector (In front of intake)

Complete the following for each SFO identified in A.3. that was ultimately discarded

---

B) SFO Alternative 1 (investigated and ultimately discarded):

1) *What modeling and prototype development was done? Present in timeline format.*
   A 3,000 cfs surface collector that was directly connected to the turbine intake was considered.
2) *History of development and testing with the decision path (testing, design considerations, performance, etc)*
   - Not provided
3) *Why was the SFO discarded as a design alternative?*
   The 3,000 cfs collector idea was discarded due to cost, the belief that passage goals could be achieved with a smaller collector and the potential negative impacts to juveniles rearing in the reservoir and downstream water quality.

Complete the following for each SFO identified in A.3. that is currently in use or under development

---

C) SFO Alternative 1 (investigated): Obermeyer Weir (River Mill Dam)

1) *What modeling and prototype development was done? Present in timeline format.*
   - An experimental bypass channel was deployed next to powerhouse to take advantage of fish behavior and movement in front of the trashracks.
2) *History of development and testing with the decision path (testing, design considerations, performance, etc)*
   - Deployment of Obermeyer Weir

   An original weir was built in 1996 to provide some downstream flow control in case of a plant trip, as there were no structures to pass water. The original weir was at the spillway crest so it was only effective when there were flashboards up. In 1999, hydraulic modeling was conducted to determine potential design of a "fish chute" to move fish down the spillway and across an exposed bedrock outcrop.
   - Biological testing from 2001-2004 indicated high percent of juveniles could be attracted to spillway.
   - Physical modeling of the spillway was done by ENSR
   - 2005-6 the 60 foot section of the spillway was notched 3 feet below the crest. Spill through the section is controlled by two Obermeyer Weirs. A 10-foot section closest to the powerhouse controls flow into the "fish chute" and a 50-foot section controls flow over a smoothed section of spillway.

D) Present status of facility:

1) *Project layout/bypass system configuration: Obermeyer Weir*
   - Trashracks along powerhouse (1" gaps) provide guidance to entrance of weir
   - Flow created from weir helps direct fish to the channel and then to spillway.
2) *Cost (Design, Construction, Evaluation)*
   - Notching the spillway and providing the two Obermeyer weirs approximately $1 million. The fish chute construction and spillway smoothing $750,000. Biological evaluation of the finished product to be conducted in 2007 is estimated at $325,000.
3) *Biological performance*
   - Radio Tag Studies leading to development of the final design.

Year	Percent of River Flow	Flow (cfs)	Species	Percent Passage Route Selection	Upstream Residence Time (hrs)
2001	5.5 – 29.1	400	Chinook	90	33
			Steelhead	74.5	11
2002	4.3 – 5.7	170	Steelhead	41.7	19
2003	30	~ 700	Coho	100	34
2004	4.7 – 7	150	Chinook	94	18
			Steelhead	97	17
			Coho	82	9

4) *Future plans*

The channel that passes from the edge of the trashracks to the fish chute will be replaced by a 500 cfs surface collector that is connected to turbine 5 intake for attraction flow. This will eliminate the need to spill water to bypass fish.

Complete the following for each SFO identified in A.3. that is currently in use or under development

---

E) SFO Alternative 3 (path to final design or SFO alternative currently being investigated): Current Surface Collector (North Fork)

1) *What modeling and prototype development was done? Present in timeline format.*
   - No prototype development because facility was constructed in 1958 as a combination adult and juvenile fish bypass facility?
2) *History of development and testing with the decision path*.

- Biological Testing
  - PIT tag Findings
    - 25,000 fish tagged over 6 years
    - Steelhead and Coho guide well 80 to 100% (no spill) generally > 95%.
    - Chinook 51% -63%
    - In years of high spill significant numbers of fish pass the spillway
  - Sonic Tag Findings (Chinook)
    - Only 2% exited through turbines
    - No difference between fish from different sources
    - Fish were surface oriented over turbine intakes.
  - Radio Tag Findings
    - Bypass efficiency for Coho and steelhead 88% to 100 %
    - Bypass efficiency for Chinook 81% to 94%
    - Most fish approached along south shore
    - Forebay residency time similar between routes (no-spill)
    - Fish averaged >1.5 forays/hr
    - Forebay residency and "lost" fish much less with spill
    - Powerhouse passage greater at flows> 3,000cfs
  - Hydroacoustic Findings
    - Fish tend to be surface oriented
    - Most fish travel parallel to the dam

F) Present status of facility:

1) *Project layout/bypass system configuration: Surface Collector*
   - Located on spillbay side of dam.
   - Facility has 240 cfs flow
   - Fish enter the bypass and travel 1.7 miles until they are diverted into a holding tank.
2) *Cost (Design, Construction, Evaluation)*
   - Not available
3) *Biological performance*
   - Fish Bypass Effectiveness (FBE) studies for Chinook 2002-2004

Study Period	Attraction flow into Bypass	Number released	FBE estimat e %	Average Daily River Flow	Median Forebay Residency Day - Hr	Min : Max Forebay Residency Day - Hr
Spring 2002	490 cfs	68	77-90	3380	1 – 02	0 - 02 : 10 - 17
Spring 2003	600 cfs	50	81-93	2450	2 - 04	0 - 01 : 15 - 15
Spring 2004	600 cfs	152	89-92	2100	2 – 06	0 – 0.2 : 18 -
Fall 2002	600 cfs	313	85-94	1500	1 – 00	0 - 0.3 : 17 -
Fall 2003	600 cfs	199	86-95	1800	1 – 05	0 - 0.1 : 15 -
Spill Studies Spill*						
Fall 2003	2000 cfs	101	23.5	3870	0 - 07	0 - 0.2 : 1 - 11
Fall 2003	2000 cfs	65	18.6	2790	0 - 05	0 - 0.5 : 1 - 08
Spring	1390 cfs	149		2960	0 - 15	0 – 0.2 : 3 - 05
*Time for 90% of Chinook to pass with no spill, was 7 days and 3 hrs and with spill 1 day and 19						

- Median Reservoir Residence Time

Study Period	Bypass	Powerhouse	Forays
Fall 2002	1 day	1 day	

Spring 2003	1.9 days	0.9, 2.2, 4.5 days (3 fish)	1.5,7.3/hr
Fall 2003	1.2 days	0.79 days	1.9/hr
Spring 2004	2 days	5 days	2.4, 2.2/hr

- Chinook Passage Related to Flow

	Percent Powerhouse Passage		
	<3,000 cfs	**>3,000 cfs**	
Spring 2002	3.1	20.0	n=20
Spring 2003	7.3	n.d.	
Spring 2004	8.0	n.d.	
Fall 2003	5.1	n.d.	
Fall 2003	2.5	26.3	n=19

4) *Future plans*
   - Currently in operation
   - Replace existing screens to meet current size (opening) criteria.

Complete the following for each SFO identified in A.3. that is currently in use or under development

---

G) SFO Alternative 3 (path to final design or SFO alternative currently being investigated): Proposed Floating Surface Collector (North Fork).

1) *What modeling and prototype development was done? Present in timeline format.*
   - *In 2004 Hydraulic modeling was conducted for two scenarios 500 cfs and 1,500 cfs surface collectors based on*
   - 500 cfs modular design
   - Entrance Depth 25 ft.
   - Entrance Width 8 ft.
   - Downward pipe diameter 7.5 ft
   - Downward pipe depth 105 ft
   - Located over turbine intakes
     - *Plan views demonstrate velocity at:*
       - *Surface*
       - *10, 20, 30, and 40 ft depths*
     - *Two profile views demonstrate velocity at:*
       - *Profile1 – forebay along the northern penstock*
       - *Profile2 – forebay along the center unit of the proposed floating screen facility*
2) *History of development and testing with the decision path*.
   - Negotiated settlement is to build a 1,000 cfs surface collector

H) Present status of facility:

1) *Project layout/bypass system configuration:*
   - We are in the design stage for a 1,000 cfs pumped surface collector.
2) *Cost (Design, Construction, Evaluation)*
   - Estimated cost is $36 million.
3) *Biological performance*
   - NA
4) *Future plans*
   - The 1,000 cfs surface collector is expected to be installed in 2012.

I) Conclusions and lessons learned (from all designs):

1) *Data gaps identified*

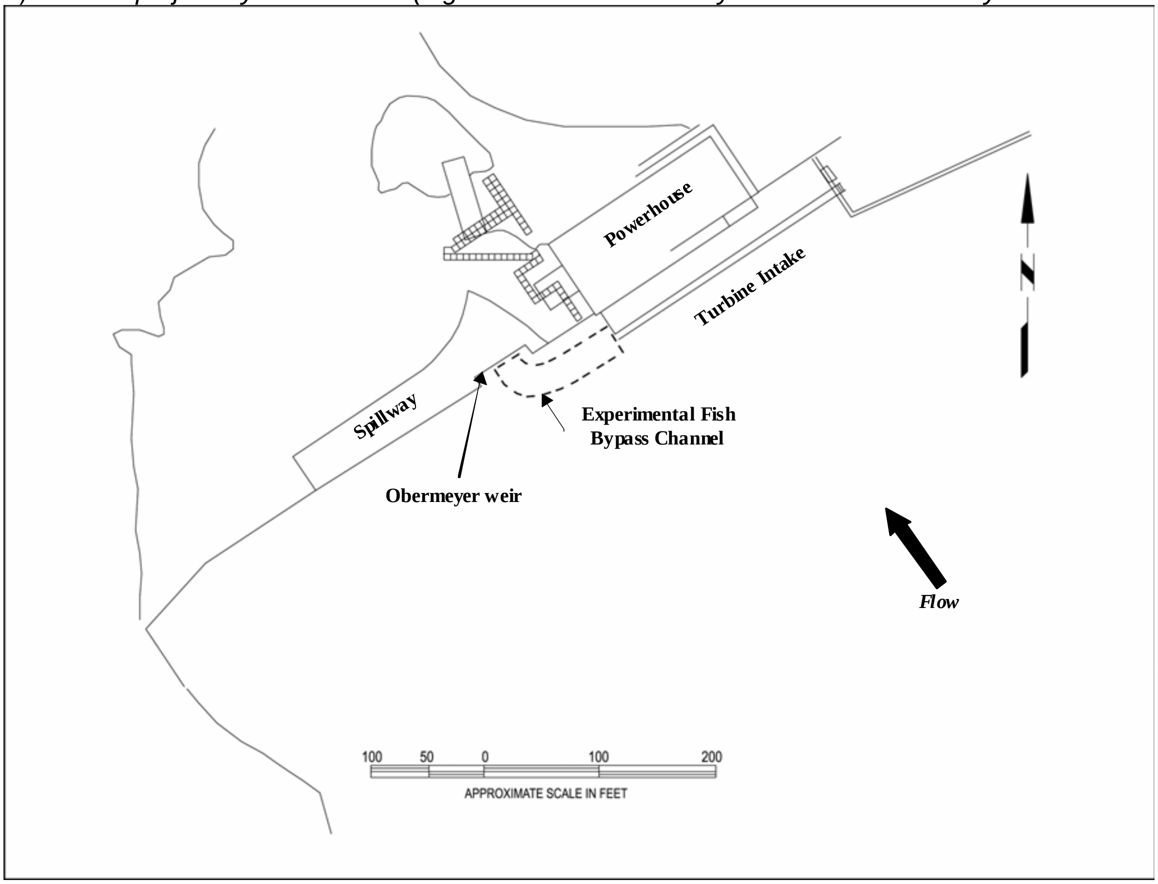
- Amount of surface attraction flow that it takes to overcome the attraction of juvenile spring chinook to the turbine intakes (depth of 120 ft.) when flow to the turbines is greater than 3,000 cfs.

2) *Guiding principles/recipes for success*
   - Information Summary Points
     – Fish tend to enter forebay along south shore
     – Fish tend to congregate near surface over intakes
     – Fish "search" for exit
     – Bypass location affects performance
     – Current bypass gets some fish out of spill
   - Assumptions supporting additional floating surface collector
     – Fish are available (time and location) for attraction
     – Entrance location will effect efficiency
     – Study fish from bypass are representative of population
     – Higher flows are better for attracting fish
     – Appropriate entrance location and flow will reduce residency and increase bypass efficiency
3) *Pit falls, i.e. what not to do*
   - Not provided
4) *Absolute requirements*
   - Not provided
5) *If you had it to do all over again, what would you do differently?*
   - Fill in data gaps before final design.

J) Exhibits:

1) *Aerial photo*

2) *Current project layout with SFO (Figure shows River Mill layout. The North Fork layout will be similar.)*

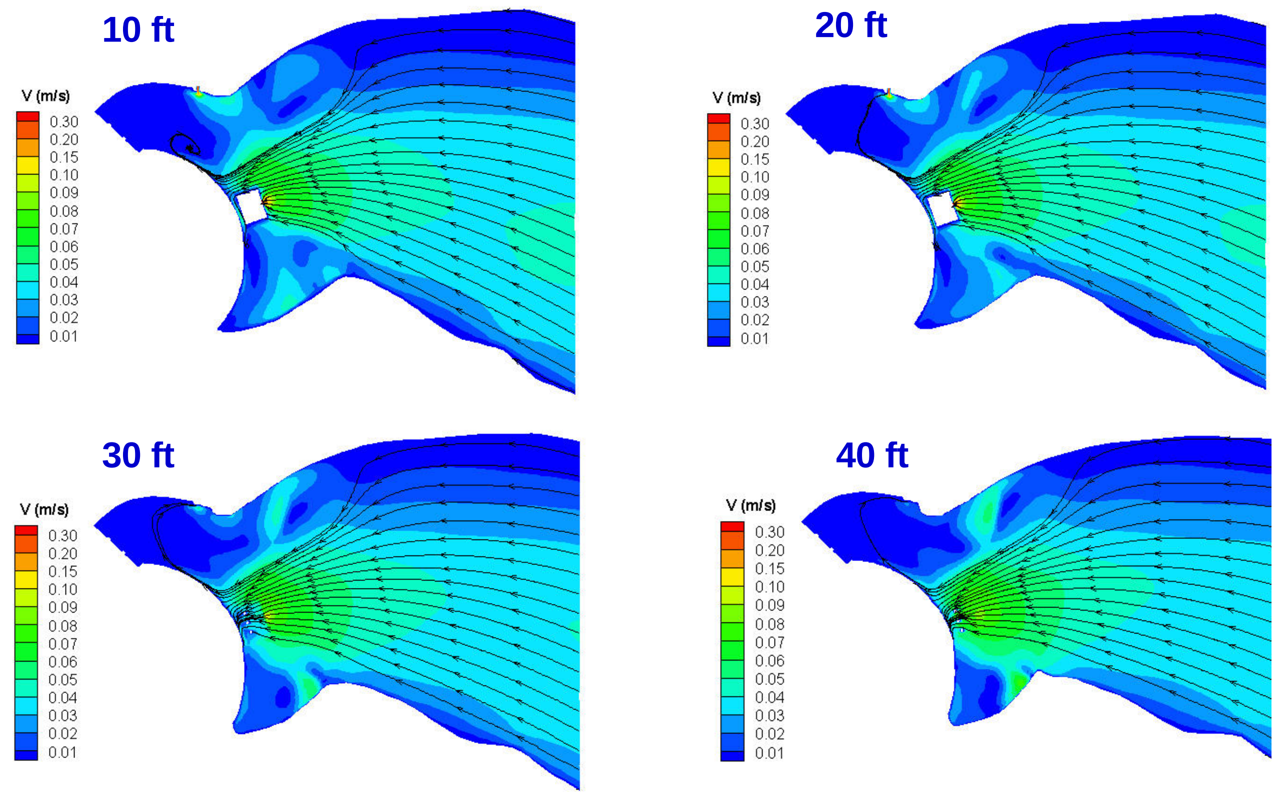


3) *Forebay and tailrace bathymetry* (Not available at this time)

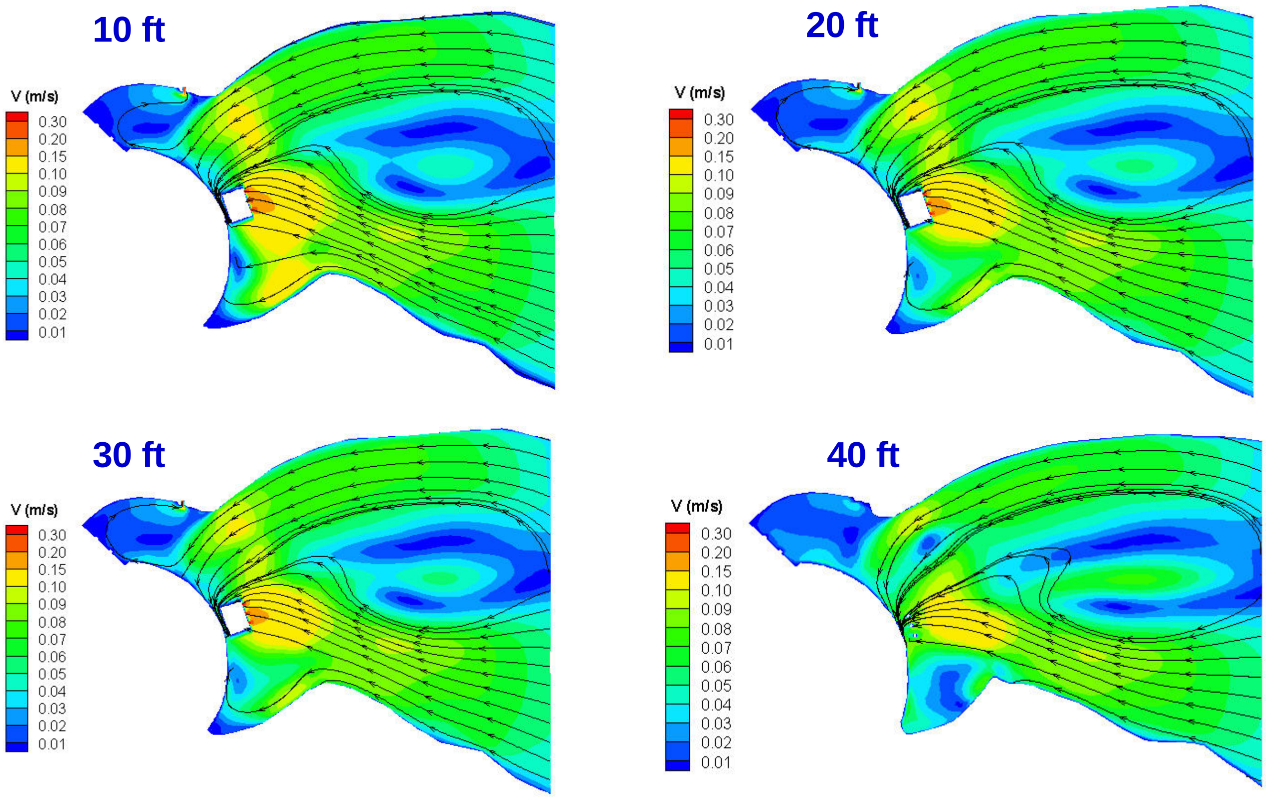
4) *Current plan and profile of the SFO structure* (Not available at this time)

5) *Forebay & tailrace flow fields*

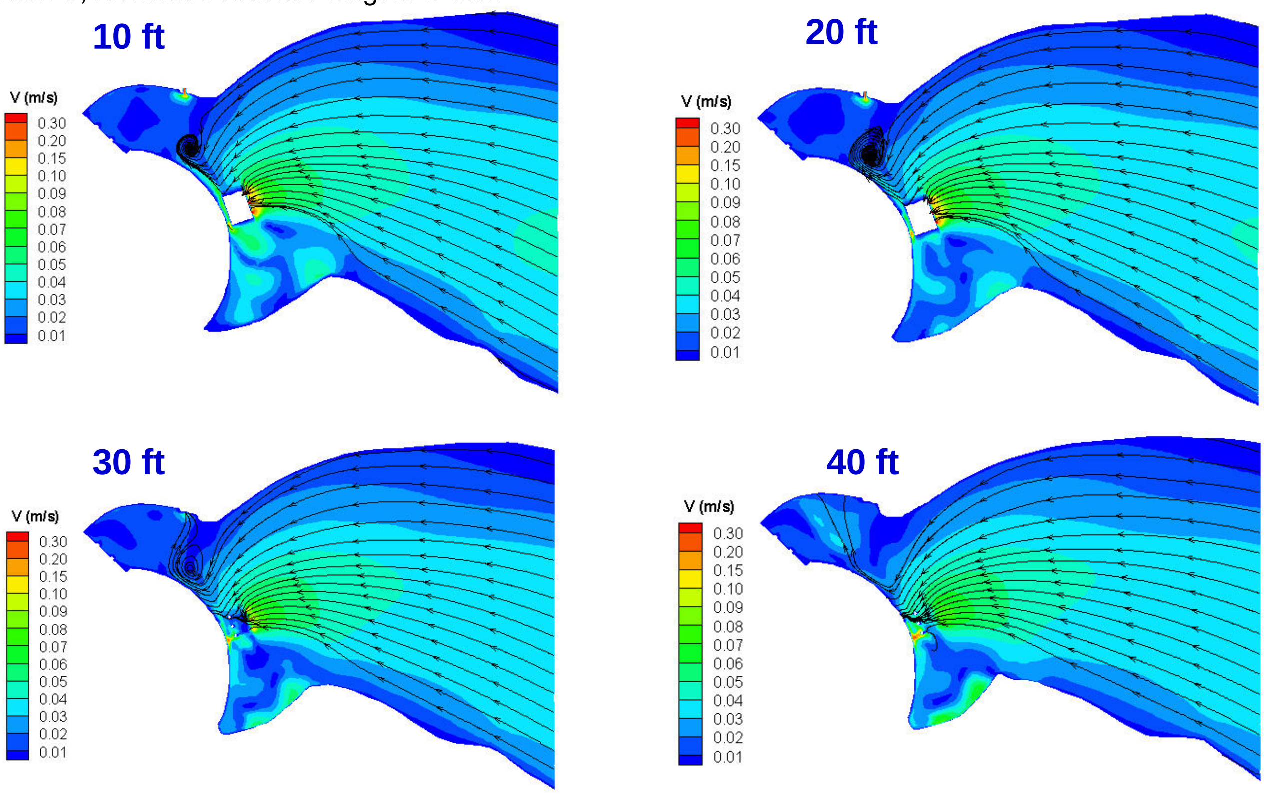
Run1 (River flow = 6070 cfs; Powerhouse flow = 6000 cf; Existing bypass = 255 cfs; Pump back = 200 cfs; New screen flow = 500 cfs; Pump back = 485 cfs)



Run 2a (River flow = 6070 cfs; Powerhouse flow = 6000 cfs; Existing bypass = 255 cfs; Pump back = 200 cfs; New screen flow = 1500 cfs; Pump back = 1485 cfs



Run 2b, reoriented structure tangent to dam



Project Description

Completed By:____________________

Email:____________________

Phone:____________________

Date:____________________

Project: Howard Hanson Surface Bypass

Presenter: ***Dan Katz***

A) Introduction:

1) *Why was SFO considered?*
   - Ultimate goal: restore self-sustaining fish run to the Upper Green River.
   - Upstream fish passage: will be provided by City of Tacoma's new trap and haul facility.
   - Major fish habitat restoration now underway above Howard Hanson Dam (construction underway).
2) *What initial data kick-started the process?*
   - Set goals
     - Reduce juvenile passage delay
     - Improve juvenile passage survival to 95%
     - No impact on existing project function
   - Specific Design Goals
     - Operating Range: 97 feet
     - Facility Flow: up to 1200 cfs
   - Meet appropriate velocity, velocity gradient, energy dissipation, and screen criteria
3) *What SFOs were investigated (model or prototype)?*
   - Multiple Near-Surface Submerged Collectors (with floating surface collector)
   - Multiple Near-Surface Submerged Collectors (without floating surface collector)

Complete the following for each SFO identified in A.3. that was ultimately discarded

B) SFO Alternative 1 (investigated and ultimately discarded): Multiple Near-Surface Submerged Collectors with floating surface collector

1) *What modeling and prototype development was done? Present in timeline format.*
   - Not provided
2) *History of development and testing with the decision path.*
   - 1:8 model of collector
     - Shaped entrance to reduce delay
   - CFD model with collector
     - At high forebay, currents stronger at surface and weaker at depth
   - At high pools, want discovery/decision flows to be stronger: small floating surface collector to replace topmost collector
   - Floating collector design goals:
     - Entrance attraction flow: up to 600 cfs
     - Forebay operating range: 22 ft
     - Trash and debris: eliminate trash rack
     - Max screen approach velocity: 0.4 ft/s
   - Floating collector design matrix

Concept	Criterion Score (1-Best to 5-Poorest)									
	Biological Performance				Other Factors					
	Attraction at Low Flow (300 cfs or less)	Attraction at Design Flow (600 cfs)	In-system Delay	Potential for Injury	Compatibility with Current Design	Operational Complexity	Design Uncertainty	Cost	Fatal Flaw	Total Score
Rolling and Pivoting Low Velocity Screen	5	4	5	2	4	3	3	3	No	29
Hoisted Low Velocity Screen	3	3	2	1	2	5	1	3	No	20
Hoisted Top MIS	2	2	2	3	1	4	2	1	No	17
Hoisted High Velocity Screen	1	1	1	2	2	1	2	2	No	12
Hoisted High Velocity Screen with Separate Fish Well	2	1	1	2	5	5	4	4	Yes *	24
Hoisted High Velocity (Coanda) Declining Screen with Separate Fish Well	5	1	1	4	5	5	5	5	Yes *	31

* Due to operational complexity

3) *Why was the SFO discarded as a design alternative?*
   - Discarded floating surface collector as design alternative because it:
     - Has a large impact on project budget ($50 million budget already exceeded)
     - Causes unacceptable delays in design, construction, and operation of the new facility

---

Complete the following for each SFO identified in A.3. that is currently in use or under development

---

C) SFO Alternative 2 (path to final design or SFO alternative currently being investigated): Multiple Near-Surface Submerged Collectors without floating collector

1) *What modeling and prototype development was done? Present in timeline format.*
   - Not provided
2) *History of development and testing with the decision path*.
   - Not provided

D) Present status of facility: Facility is still under development, no present SFO facility

1) *Project layout/bypass system configuration:*
   - Not currently available
2) *Cost (Design, Construction, Evaluation)*
   - Not currently available
3) *Biological performance*
   - Not currently available
4) *Future plans*
   - Facility currently under construction
   - After facility is operational, performance will be monitored
   - If warranted, a small-scale surface collector may be added in the future, above existing collectors
   - Surface collection will probably only be added if pool is raised to 1177 ft.
   - Surface collection, if provided, will probably 300 cfs or less

---

E) Conclusions and lessons learned (from all designs):

1) *Data gaps identified*
   - Lack of fish; limited studies; must assume behavior and timing
2) *Guiding principles/recipes for success*
   - Have good coordination between reservoir regulation and operation
   - Design for debris handling
   - Design for operational flexibly
3) *Pit falls, i.e. what not to do*
   - Not currently available
4) *Absolute requirements*
   - Not currently available
5) *If you had it to do all over again, what would you do differently?*

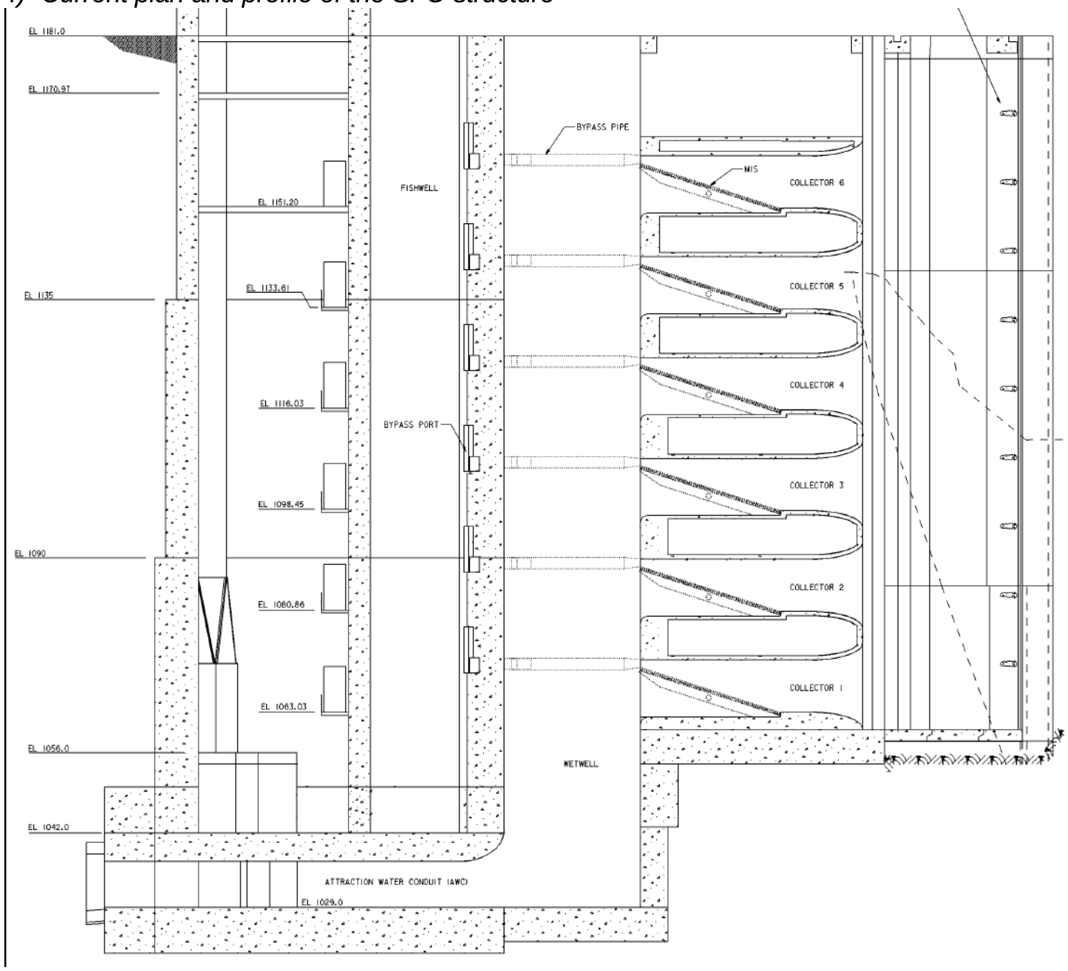
- Not currently available

F) Exhibits:

1) Aerial photo

2) *Current project layout with SFO* (Facility still under development, not currently available)
3) *Forebay and tailrace bathymetry* (Facility still under development, not currently available)

4) Current plan and profile of the SFO structure



5) *Forebay & tailrace flow fields*

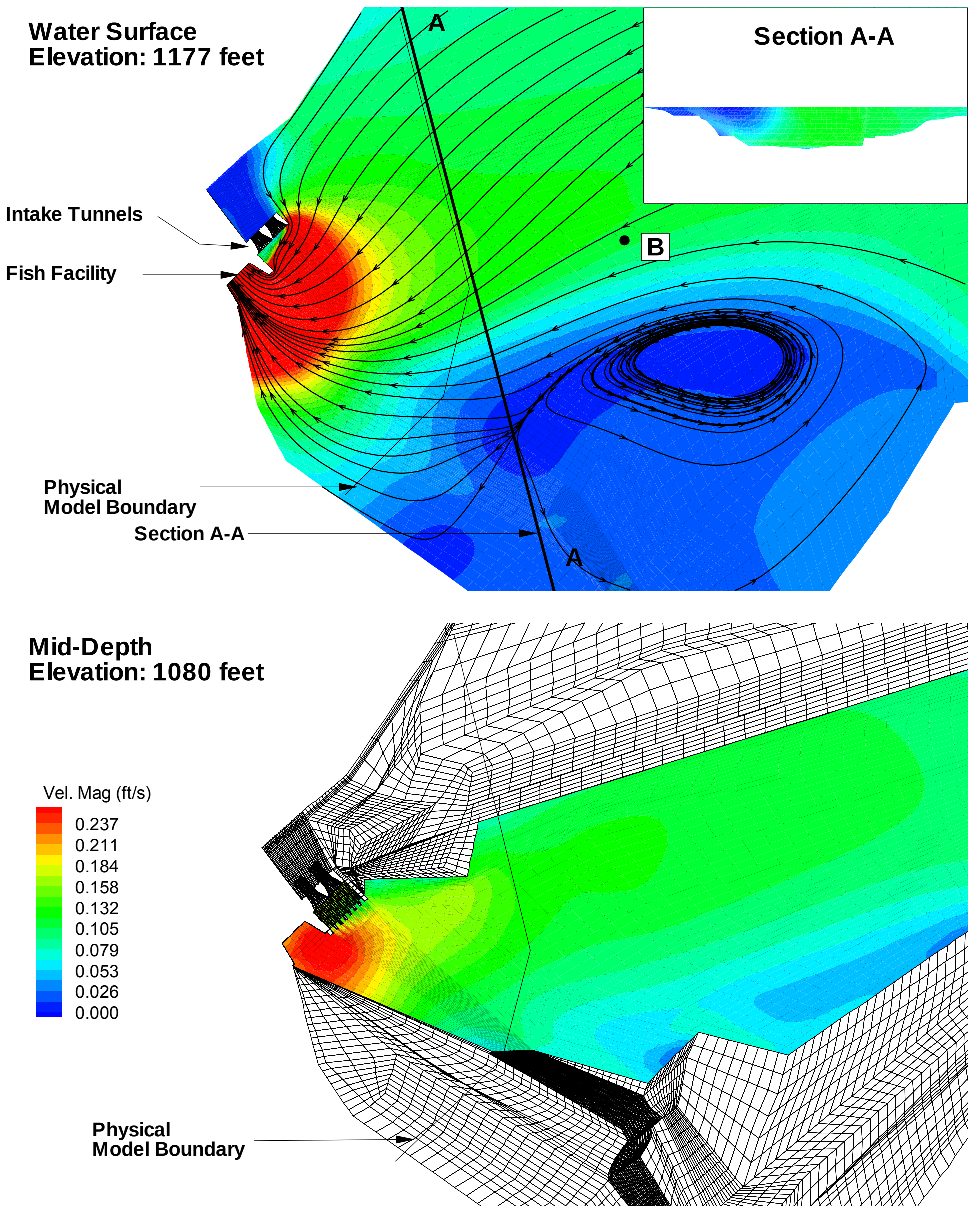


Figure 5: Plan View of Velocity Magnitude at Water Surface and Mid-Depth

Scenario S4P1: Tunnel: 0 cfs, Fish: 1300 cfs

General Stats:

- Reservoir Length: 5 miles
- Depth: can exceed 140 feet
- Pool Fluctuation: 100 ft
- Fish: Coho, Chinook, Steelhead
- Concrete Spillway: Capacity 107 Kcfs
- Spillway Tainter Gates: 45 x 30 ft
- Length at Crest: 450 ft
- Outlet Tunnel:

  - 19 ft wide x 900 ft long
  - 2 Tainter Gates, 10 x 12 ft
  - Normal Capacity: 10 kcfs
  - Tunnel Bypass Pipe: 0.5 kcfs
- Tailrace features:
  - Emergency spillway
  - Outlet Tunnel
  - Stilling Basin
  - Tunnel Bypass Pipe Exit
- Forebay flow field analysis
  - Without Fish Facility, Existing Tunnel Only, Low Pool, High Flow: Note Strong Surface Current at Low Pool
  - Without Fish Facility, Existing Tunnel Only, High Pool, High Flow: Note Weaker Surface Current at High Pool
- No power generation at this dam. Only flood control and water storage.

ENSR | AECOM

Appendix D

Annotated Bibliography

Reference List: Table of Contents

Reference List: Sorted By Project and Discipline

D.1 Mid-Columbia River Reference List

D.1.1 Wells Reference List

D.1.1.1 Wells: Engineering Design

1. ENSR. 1994. Bathymetric Survey of Wells Hydroelectric Project Forebay. Report Submitted to Svedrup. ENSR, Redmond, WA.*

2. Sverdrup and Parcel and Associates, Inc. 1985. Prototype Bypass Study. Report Prepared for DCPUD.*

3. Sverdrup and Parcel and Associates, Inc. 1982. Prototype Juvenile Salmon Bypass Study. Report Prepared for DCPUD.*

D.1.1.2 Wells: Biological Evaluation

1. BioSonics, Inc. 1982. Hydroacoustic Assessment of Downstream Migrating Salmonids at Wells Dam in 1982. BioSonics, Inc., Seattle, WA. Report prepared for Douglas County PUD No. 1, East Wenatchee, WA.

2. BioSonics, Inc. 1983. Hydroacoustic Monitoring and Distribution of Downstream Migrant Salmonids and Evaluation of the Prototype Bypass System at Wells Dam in Spring, 1983. Report Prepared for Douglas County PUD No. 1, East Wenatchee, WA. BioSonics, Inc., Seattle, WA.

3. Erho, M.W., G.E. Johnson, and C.M. Sullivan. 1988. The Salmonid Smolt Bypass System at Wells Dam on the Columbia River.

4. Johnson, G. and C. Sullivan. 1985. Summary of Hydroacoustic Run Timing and Distribution Studies of Downstream Migrant Salmon and Steelhead at Wells Dam From 1981 to 1984. Draft Report Prepared for Douglas County PUD No. 1, East Wenatchee, WA. BioSonics, Inc. Seattle, WA.*

5. Johnson, G.E. 1996. Fisheries Research on Phenomena in the Forebay of Wells Dam in Spring 1995 Related to the Surface Flow Smolt Bypass. Report Prepared for the U. S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA. Battelle Pacific Northwest National Laboratory, Richland, WA.*

6. Johnson, G.E. and C.M. Sullivan. 1986. Hydroacoustic Evaluation of the Prototype Smolt Bypass System at Wells Dam in 1985. Report Prepared for Douglas County PUD No. 1, East Wenatchee, WA. BioSonics, Inc., Seattle, WA.

7. Johnson, G.E., C.M. Sullivan, and M.W. Erho. 1992. Hydroacoustic Studies for Developing a Smolt Bypass System at Wells Dam. *Fisheries Research*. 14: 221-237.*

8. Kudera, E.A. and C.M. Sullivan. 1993. Evaluation of The Smolt Bypass System at Wells Dam in 1992. Report Prepared for Douglas PUD No. 1, East Wenatchee, WA. BioSonics, Inc. Seattle, WA.

---

* Report has been annotated; see annotated references starting on page D-47.

9. Kudera, E.A., C.M. Sullivan, and G.E. Johnson. 1991. Evaluation of The Smolt Bypass System at Wells Dam in 1990. Report Prepared for Douglas PUD No. 1, East Wenatchee, WA. BioSonics, Inc. Seattle, WA.

10. Kudera, E.A., C.M. Sullivan, G.E. Johnson, and A.G. Birmingham. 1992. Evaluation of The Smolt Bypass System at Wells Dam in 1991. Report Prepared for Douglas PUD No. 1, East Wenatchee, WA. BioSonics Inc., Seattle, WA.

11. McGee, J. 1984. Juvenile Salmonid Monitoring in the Wells Dam Forebay April-May 1984. Douglas County PUD, East Wenatchee, WA.*

12. McGee, J. 1984. Migration Timing of Juvenile Salmonids in the Wells Dam Forebay April July 1984. DCPUD.*

13. McGee, J. and K. Truscott. 1982. Juvenile Salmonid Monitoring Okanogan River and Wells Dam Forebay, April-May 1982. DCPUD.*

14. Olson, F.W. 1984. Depth Distribution of Juvenile Salmonids Entering the Turbine Intakes at Wells Dam. Draft Report Submitted to Douglas County PUD, East Wenatchee, WA. CH2M-Hill.*

15. Skalski, J.R., G.E. Johnson, C.M. Sullivan, E. Kudera, and M.W. Erho. 1996. Statistical Evaluation of Turbine Bypass Efficiency at Wells Dam on the Columbia River, Washington. *Canadian Journal of Fisheries and Aquatic Sciences*. 53(10).*

16. Sullivan, C.M., G.E. Johnson, and E.A. Kudera. 1988. Smolt Monitoring Program and Hydroacoustic Evaluation of Characteristics of the Smolt Bypass System at Wells Dam in 1988. Report Prepared for Douglas County PUD No. 1, East Wenatchee, Washington. BioSonics, Inc, Seattle, Washington.

17. Weitkamp, D. and J. Neuner. 1981. Juvenile Salmonid Monitoring Methow River, Okanogan River, and Wells Dam Forebay April-May 1981. Report Submitted to DCPUD. Parametrix, Inc.*

18. Weitkamp, D.E., D. McKenzie, and T. Schadt. 1980. Survival of Steelhead Smolts During Passage Through Wells Dam Turbines and Spillways. Report Prepared for Douglas County PUD, East Wenatchee, WA. Parametrix, Inc., Bellevue, WA.*

19. Weitkamp, D.E., D. McKenzie, and T. Schadt. 1981. Survival of Steelhead Smolts: Wells Dam Turbines and Spillway. Report Prepared for Douglas County PUD No. 1, East Wenatchee, WA. Parametrix, Inc., Bellevue, WA.

D.1.1.3 Wells: Physical Modeling

1. Copp, H.D. and J.S. Gladwell. 1964. Hydraulic Model Studies Wells Hydroelectric Project. Volume I. Comprehensive Model Studies. Report Submitted to Bechtel. Washington State University.*

2. Rudavsky, A.B. and J.R. Oberg. 1982. Two-Dimensional Model Study of Typical Hydro-Combine Section for the Wells Hydroelectric Project. Report Submitted to DCPUD. Hydro Research Science.*

D.1.2 Rocky Reach Reference List

D.1.2.1 Rocky Reach: Engineering Design

1. Christman, W.G. and B.M. Bickford. 1998. Safely Moving Migratory Fish Through Rocky Reach Dam. *Hydro Review*. June.

2. CH2M Hill and Duke Engineering Services. 2000. Design Development Report for Rocky Reach Fish Bypass Production System, Surface Collection and Bypass Conduit. December 11, 2000.

3. CH2M Hill and Duke Engineering Services. 2001. Rocky Reach Juvenile Fish Bypass. Design Report, Surface Collector and Bypass Conduit Projects. Final Report. September 2001.

4. CH2M Hill. 2003. Hydraulic Commissioning Report. Rocky Reach Juvenile Fish Bypass. Prepared for Public Utility District No. 1 Chelan County, Washington. December 2003.

5. ENSR. 1997. Field Calibration and Start-Up of Rocky Reach 1997 Surface Collector Prototype (SCP). Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

6. ENSR. 1996. Field Calibration of Rocky Reach 1996 Surface Collector Prototype. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

7. ENSR. 1996. Rocky Reach Dam Juvenile Fish Bypass 1996 Surface Collection Prototype Primary Screen Velocity Measurements. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

8. ENSR. 1999. Rocky Reach Dam Juvenile Fish Bypass 1998 Prototype Start-Up and Calibration Results. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

9. ENSR. 2000. Rocky Reach Dam Juvenile Fish Bypass 1999 Prototype Start-Up and Calibration Results. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

10. ENSR. 1998. Rocky Reach Dam Juvenile Fish Bypass Comparison of 1998 Prototype 1:30 Model and Field Collector Entrance Velocity Data. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

11. ENSR. 1996. Rocky Reach Dam Juvenile Fish Bypass Forebay Flow Characteristics for the 1995 and 1996 Surface Collection Prototypes. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

12. ENSR. 2001. Rocky Reach Dam Juvenile Fish Bypass Systems Development of the 1999 Surface Collection Prototype. Final Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

13. ENSR. 1999. Rocky Reach Juvenile Fish Bypass Impacts of Production System Options on Forebay Hydraulics. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

14. IIHR. 2001. Rocky Reach Weirbox Hydraulic Gradeline Studies. Letter from Iowa Institute of Hydraulic Research to Public Utility District No. 1 of Chelan County dated May 30, 2001.

15. NHC. 2001. Rocky Reach Dam Surface Collector. Weir Box Development Studies. Final Report for Public Utility District No. 1 of Chelan County. Prepared by northwest hydraulic consultants. June 2001.

16. Sweeney, C.E., B. Christma, and D.E. Weitkamp. 1997. Update on Juvenile Fish Bypass at Rocky Reach Dam. Waterpower.*

D.1.2.2 Rocky Reach: Biological Evaluation

1. Adeniyi, R., T.W. Steig, J.E. Keister, and V. Locke. 1998. Hydroacoustic Evaluation of the Behavior of Juvenile Salmon and Steelhead Approaching the Powerhouse of Rocky Reach Dam During Spring and Summer 1997. Final Report. Report prepared for Chelan County PUD No. 1 Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

2. Adeniyi, R. and T.W. Steig. 1999. Hydroacoustic Evaluation of the Behavior of Juvenile Salmon and Steelhead Approaching the Two Surface Collectors and the Powerhouse of Rocky Reach Dam During Spring of 1998. Final Report. Hydroacoustic Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

3. Adeniyi, R. and T.W. Steig. 1995. Hydroacoustic Evaluation of the Fish Passage Through Units 1-5, and the Juvenile Surface Collector at Rocky Reach Dam in the Spring and Summer of 1995. Hydroacoustics Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.*

4. English, K.K., C. Sliwinski, J.J. Smith, J.R. Stevenson, and T.R. Mosey. 2000. Evaluation of Juvenile Spring Chinook, Steelhead, and Sockeye Migratory Patterns at Rocky Reach Dam Using Radio-Telemetry Techniques, 2000. LGL Limited, Sidney, B.C., Canada. Report prepared for Chelan County PUD No. 1 Wenatchee, WA.*

5. English, K.K., R.C. Bocking, C. Sliwinski, J.R. Stevenson, and T.R. Mosey. 1999. Evaluation of Juvenile Spring Chinook, Steelhead, and Sockeye Migratory Patterns at Rocky Reach Dam Using Radio-Telemetry Techniques, 1999. Report Prepared for Chelan County PUD No. 1 Wenatchee, WA. LGL Limited, Sidney, B.C., Canada.*

6. English, K.K., T.C. Nelson, C. Sliwinski, J.R. Stevenson, and T.R. Mosey. 1998. Evaluation of Juvenile Spring Chinook, Steelhead, and Sockeye Migratory Patterns at Rocky Reach Dam Using Radio-Telemetry Techniques 1998. LGL Limited, Sidney, B.C., Canada. Report prepared for Chelan County PUD No. 1 Wenatchee, WA.*

7. Hays, S. 1984. Determination of the Depth Distribution of Juvenile Salmonids in the Turbine Intakes at Rocky Reach and Rock Island Dams. Chelan County Public Utility District, Wenatchee, WA. *

8. Lady, J., J.R. Stevenson, J.R. Skalski, and A.E. Giorgi. 2000. A Pilot Study to Estimate Route-Specific Survival and Passage Probabilities of Steelhead Smolts at Rocky Reach and Rock Island Dams, 1999. Report Prepared for Chelan County PUD No. 1, Wenatchee, WA. Columbia Basin Research, School of Fisheries, University of Washington, Seattle, WA.

9. Normandeau Associates and J.R. Skalski. 2000. Passage Survival Investigation of Juvenile Chinook Salmon through a Bypass Pipe on the Columbia River, Washington. Prepared for Public Utility District No. 1 of Chelan County. December 2000.

10. Peven, C.M. and A.M. Abbott. 1994. Rocky Reach Fish Guidance System 1994 Developmental Testing. Chelan County PUD No. 1, Wenatchee, WA.

11. Peven, C.M., A.M. Abbott, and B.M. Bickford. 1995. Biological Evaluation of the Rocky Reach Surface Collector, 1995. Chelan County PUD No. 1, Wenatchee, Washington.*

12. Peven, C.M., T.R. Mosey, and K.B. Truscott. 1996. Biological Evaluation of the Rocky Reach Surface Collector 1996. Final Report. Chelan County Public Utility District, Wenatchee, Washington.*

13. Peven, C. M. and T.R. Mosey. 1998. Biological and Hydraulic Evaluation of the Rocky Reach Surface Collector 1997. Final report. Chelan County Public Utility District, Wenatchee, Washington. January 12, 1998.

14. Raemhild, G., T. Steig, R. Riley, and S. Johnston. 1984. Hydroacoustic Assessment of Downstream Migrating Salmon and Steelhead at Rocky Reach Dam in 1983. Final report by Biosonics for Chelan County PUD.

15. Skalski, J.R., R. Townsend, J. Lady, A.E. Giorgi, J. R. Stevenson, and R. D. McDonald. 2002. Estimating Route-Specific Passage and Survival Probabilities at a Hydroelectric Project From Smolt Radiotelemetry Studies. *Canadian Journal of Fisheries and Aquatic Sciences. 59: 1385-1393.**

16. Steig, T.W. 1993. Hydroacoustic Evaluation of Juvenile Salmon and Steelhead Approaching Units 1-5 at Rocky Reach Dam During the Summer of 1992. BioSonics, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.*

17. Steig, T.W. 2001. Review of Acoustic Tag Study Results at Rocky Reach and Rock Island Dams From 1998 Through 2001. Report Prepared for Chelan County PUD No. 1 Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

18. Steig, T.W. and A.E. Sullivan. 1991. Hydroacoustic Evaluation of the Horizontal Distribution of Juvenile Salmon and Steelhead Across the Powerhouse at Rocky Reach Dam During 1990. Hydroacoustic Technology Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

19. Steig, T.W. and R. Adeniyi. 1999. Hydroacoustic Evaluation of Fish Passage Through a Prototype Surface Bypass Collector at Rocky Reach Dam. Odeh, M., Editor. Innovations in Fish Passage Technology. American Fisheries Society, Bethesda, Maryland. pp. 93-105.

20. Steig, T.W., J.W. Horchik, and M.A Timko. 2001. Monitoring Juvenile Chinook and Steelhead Migration Routes With Acoustic Tags in the Forebay of the Powerhouse and Spillway of Rocky Reach Dam in 2000. Hydroacoustic Technology Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1, Wenatchee, Washington.*

21. Steig, T.W. and M.A. Timko. 2000. Using Acoustic Tags for Monitoring Juvenile Chinook and Steelhead Migration Routes in The Forebay of Rocky Reach Dam During The Spring and Summer of 1999. Hydroacoustics Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

22. Steig, T.W., P. A. Nealson, K. K. Kumagai, L. S. Brown, G.W. Tritt, K.C. Molitor, J. W. Horchik, M.A. Timko, J.C. Sweet, and C. P. Mott. 2006. Route Specific Passage of Juvenile Steelhead, Chinook, and Sockeye Salmon Using Acoustic Tag Methodologies at Rocky Reach and Rock Island Dams in 2005. Report Prepared for Chelan County PUD No. 1, Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

23. Steig, T.W., P.A. Nealson, K.K. Kumegai, J.W. Horchik, C.P. Mott, and J.C. Sweet. 2006. Route

Specific Passage of Juvenile Chinook, Steelhead, and Sockeye Salmon Using Acoustic Tag Methodologies at Rocky Reach and Rock Island Dams in 2004. Report Prepared for Chelan County PUD No. 1, Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

24. Steig, T.W. and R. Adeniyi. 1999. Hydroacoustic Evaluation of Fish Passage Through the Powerhouse and Surface Collectors at Rocky Reach Dam in the Spring of 1998. Final Report. Hydroacoustics Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.*

25. Steig, T.W. and R. Adeniyi. 1995. Hydroacoustic Evaluation of the Behavior of Juvenile Salmon and Steelhead Approaching the Powerhouse in the Forebay of Rocky Reach Dam During 1995. Hydroacoustic Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.*

26. Steig, T.W. and R. Adeniyi. 1997. Hydroacoustic Evaluation of the Behavior of Juvenile Salmon and Steelhead Approaching the Powerhouse of Rocky Reach Dam During Spring and Summer 1996. Final Report. Hydroacoustic Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.*

27. Steig, T.W. and R. Adeniyi. 1996. Hydroacoustic Evaluation of the Fish Passage Through Units 1-11, Spillways 3-5 and the Surface Collector at Rocky Reach Dam in the Spring and Summer of 1996. Hydroacoustic Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.*

28. Steig, T.W., R. Adeniyi, T.K. Iverson, and T.C. Torkelson. 1999. Using Acoustic Tags for Monitoring Fine Scale Migration Routes of Juvenile Salmonids in The Forebay of Rocky Reach Dam in 1998. Final Report. Hydroacoustic Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

29. Steig, T.W., R. Adeniyi, and V. Locke. 1997. Hydroacoustic Evaluation of the Fish Passage Through the Powerhouse, the Spillways, and the Surface Collector at Rocky Reach Dam in the Spring and Summer of 1997. Hydroacoustic Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.*

30. Stevenson, J.R., A.E. Giorgi, W.R Koski, K.K English, and C.A. Grant. 1997. Evaluation of Juvenile Spring Chinook and Steelhead Migratory Patterns at Rocky Reach and Rock Island Dams Using Radio Telemetry Techniques, 1996. Report Prepared for Chelan County PUD No. 1 Wenatchee, Washington. BioAnalysts, Inc., Redmond, Washington.*

31. Stevenson, J.R., J.R. Skalski, P. Westhagen, and A.E. Giorgi. 2004. Fish Passage Efficiency of Juvenile Yearling and Subyearling Chinook, Steelhead and Sockeye at Rocky Reach and Rock Island Dams, 2003: Telemetry Investigation. Chelan County PUD, Wenatchee, Washington.*

32. Truscott, K. B. and S.G. Hays. 1989. Rocky Reach Fish Guidance System 1988 Developmental Testing. Public Utility District No. 1 of Chelan County. January 16, 1989.

D.1.2.3 Rocky Reach: Physical Modeling

1. ENSR. 1995. Hydraulic Model Studies of Downstream Juvenile Fish Bypass Systems at Rocky Reach Dam Forebay Field Data Collection, Model Preparation, and Investigation of Diversion Screen System for 1994 Prototype Tests. Final Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

2. ENSR. 1998. Hydraulic Model Studies of Downstream Juvenile Fish Bypass Systems at Rocky Reach Dam: Development of the 1998 Prototype. Final Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

3. ENSR. 1997. Rocky Reach Dam Juvenile Fish Bypass 1:12 Scale Modeling of 1997 Surface Collector Prototype Primary Screen and Bypass Channel. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

4. ENSR. 1998. Rocky Reach Dam Juvenile Fish Bypass 1996 Base Model Tests. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

5. ENSR. 1998. Rocky Reach Dam Juvenile Fish Bypass Systems: Outfall Site Selection and Documentation. Final Report. Prepared for Public Utility District No. 1 of Chelan County. ENSR, Redmond, WA. ENSR document no. 1394-006-701.*

6. ENSR. 2001. Rocky Reach Dam Juvenile Fish Bypass Systems Permanent Intake Screen and Surface Collector Design Development and Documentation. Final Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.*

7. IIHR. 2001. Hydraulic Model Study for Rocky Reach Fish Bypass Sampling Screen. Letter from Iowa Institute of Hydraulic Research to Public Utility District No. 1 of Chelan County dated May 15, 2001.

8. Sweeney, C.E., Christman, B., and Weitkamp, D.E. 1995. Surface Attraction Fish Bypass at Rocky Reach Dam. Waterpower.*

9. UWRL. 2001. Rocky Reach Dam Juvenile Fish Bypass Conduit. Supercritical Bend Flow and Hydraulic Jump Characterization Model. Prepared for CH2M Hill by Utah Water Research Laboratory, Logan Utah. Report No. 561 February 2001.

D.1.2.4 Rocky Reach: Multidisciplinary

1. District Staff, et. al. 1995. Rocky Reach Dam and Rock Island Dam Fish Bypass Annual Project Team Report for Period Ending December 1994. Summary Report Prepared for Public Utility District No. 1 of Chelan County, Washington.*

2. McKee, C.A., W.G. Christman, and A.W. Showalter. 1997. Rocky Reach: Gaining New Equipment, Skills for a New Century. *Hydro Review*. 16(2):SR8-SR12.

3. Mosey, T.R., K.G. Murdoch, and B.M. Bickford. 2000. Biological and Hydraulic Evaluation of the Rocky Reach Fish Bypass System 1999. Chelan County PUD No. 1, Wenatchee, WA.*

4. Mosey, T.R., K.G. Murdoch, and B.M. Bickford. 1999. Biological and Hydraulic Evaluation of the Rocky Reach Surface Collector 1998. Final Report. Chelan County PUD No. 1, Wenatchee, WA.*

5. Mosey, T.R., K. G. Murdoch, and B. M. Bickford. 2001. Biological and Hydraulic Evaluation of the Rocky Reach Surface Collector 2000. Final Report. Chelan County PUD No. 1, Wenatchee, WA.*

6. Murphy, L.J. and T.R. Mosey. 2002. Biological and Hydraulic Evaluations of the Rocky Reach Fish Bypass System 2001. Final Report. Chelan County PUD No. 1, Wenatchee, WA.*

7. Murphy, L.J., T.R. Mosey, and P.M. Hulbert. 2001. Biological and Hydraulic Evaluation of the Rocky Reach Fish Bypass System 2000 - Final Report. Chelan County PUD No. 1, Wenatchee, WA.

8. Parametrix, Inc. 1996. Surface Collector Production System - Rocky Reach Project - Draft Design Guidance Document.

9. Peven, C.M. and T.R. Mosey. 1999. Development of Surface Bypass and Collection at Rocky Reach Dam, Columbia River. Pages 79-93 *in* M. Odeh (Ed.), Innovations in Fish Passage Technology. American Fisheries Society, Bethesda, Maryland.

D.1.3 Rock Island Reference List

D.1.3.1 Rock Island: Engineering Design

1. USACE. 2005. Total Dissolved Gas Exchange at Rock Island Dam, Over/Under Spill, March 2005. Prepared by U. S. Army Engineer Research and Development Center, Vicksburg, MS.

2. Weber, L., J. DenBleyker, and D. DeJong. 1996. Analysis of Rock Island Forebay Surface Flowlines for Public Utility District #1 of Chelan County. June 1996.

D.1.3.2 Rock Island: Biological Evaluation

1. Elder, R. A. and D.E. Weitkamp. 1990. Evaluations of 1988 Diversion Screen System at Rock Island Powerhouse No. 2. Elder Consulting and Parametrix for Chelan County PUD, Wenatchee, WA.

2. Fielder, P.C. 1989. Rock Island Dam Second Powerhouse Bar Screen Fish Guidance Tests, 1988. Chelan County Public Utility District, Wenatchee, WA.

3. Gyldenege, G.C., B.H. Ransom, and W.R. Ross. 1983. Hydroacoustic Assessment of Downstream Migrating Salmon and Steelhead at Rock Island Dam in 1982, Final Report. Report Prepared for Chelan County Public Utility District, Wenatchee, WA. Seattle, WA, BioSonics, Inc.

4. Hays, S. 1984. Determination of the Depth Distribution of Juvenile Salmonids in the Turbine Intakes at Rocky Reach and Rock Island Dams. Chelan County Public Utility District, Wenatchee, WA.*

5. Iverson, T.K. and A.G. Birmingham. 1998. Hydroacoustic Evaluation of Spill Effectiveness at Rock Island Dam During Spring and Summer, 1998, Final Report. Chelan County PUD No. 1, Wenatchee, WA.

6. Iverson, T.K., J.E. Keister, and R.D. McDonald. 1999. Summary of the Evaluation of Fish Passage Through Three Surface Spill Gate Designs at Rock Island Dam in 1996. Odeh, M., Editor. Innovations in Fish Passage Technology. American Fisheries Society, Bethesda, Maryland. pp. 129-143.

7. Iverson, T.K., J. Keister, and T.W. Steig. 1996. Hydroacoustic Evaluation of Three Surface Flow Spill Gate Designs and Overall Fish Passage at Rock Island Dam in 1996. Final Report. Hydroacoustic Technology, Inc., Seattle, Washington.*

8. Iverson, T.K., and J.E. Keister. 1997. Hydroacoustic Evaluation of Notched Surface Flow Spill Gates and Overall Fish Passage at Rock Island Dam in 1997. Report by Hydroacoustic Technology, Inc. to Chelan Co. PUD, Wenatchee, WA.

9. Lady, J., J.R. Stevenson, J.R. Skalski, and A.E. Giorgi. 2000. A Pilot Study to Estimate Route-Specific Survival and Passage Probabilities of Steelhead Smolts at Rocky Reach and Rock Island Dams, 1999. Report Prepared for Chelan County PUD No. 1, Wenatchee, WA. Columbia Basin Research, School of Fisheries, University of Washington, Seattle, WA.

10. Normandeau Associates and J.R. Skalski. 1997. Turbine Passage Survival of Chinook Salmon Smolts at The Rock Island Dam Powerhouse I and II, Columbia River, WA. September 1997.

11. Normandeau Associates, Inc. and J. Skalski. 2000. 1999 Spillway Passage Survival Investigation of Juvenile Chinook Salmon at Rock Island Dam, Washington. Chelan Public Utility District, Wenatchee, WA.

12. Normandeau Associates Incorporated and J.R. Skalski. 2001. Survival Condition of Juvenile Chinook Salmon at Rock Island Dam Spillway with a Submerged Flow Deflector. Prepared for Public Utility District No. 1 of Chelan County.

13. Normandeau Associates Incorporated and J.R. Skalski. 2002. Juvenile Chinook Salmon and Condition after Passage Through a Slotted Spillbay with a Shallow Flow Deflector at Rock Island Dam, Columbia River, Wash. Prepared for Public Utility District No. 1 of Chelan County.

14. Normandeau Associates Incorporated and J.R. Skalski. 2005. Juvenile Chinook Salmon Survival and Condition after Passage Through a Spillbay Equipped with a Prototype Over/under Flow Regulation Gate at Rock Island Dam, Columbia River, Wash. Prepared for Public Utility District No. 1 of Chelan County.

15. Peven, C.M. and R.D. McDonald. 1994. Fish Guidance System Developmental Testing at Rock Island Dam Powerhouse No. 1, Spring and Summer - 1994. Chelan County Public Utility District, Wenatchee, WA.

16. Raemhild, G.A., T.W. Steig, E.S. Kuehl, S. Johnston, and J. Condiotty. 1985. Hydroacoustic Evaluation of Juvenile Salmon and Steelhead Movement Past a Bar Screen Deflector at Rock Island Dam Powerhouse No. 2 in 1988. Hydroacoustic Technology, Inc., Seattle, WA. 1985.

17. Skalski, J.R., A.E. Giorgi, J. Lady, J.R. Stevenson, R. Townsend, and K. English. 2000. A Study to Estimate Route-Specific Survival and Passage Probabilities of Chinook Salmon and Steelhead Smolts at Rock Island Dam, 2000. Public Utility District No. 1 of Chelan County, Wenatchee, Washington.*

18. Steig, T.W. 2001. Review of Acoustic Tag Study Results at Rocky Reach and Rock Island Dams From 1998 Through 2001. Report Prepared for Chelan County PUD No. 1 Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

19. Steig, T.W. and B.H. Ransom. 1991. Hydroacoustic Evaluation of the Effectiveness of Passing Downstream Juvenile Salmon Through the South Channel Spillway at Rock Island Dam During the Summer of 1990. Chelan County PUD No. 1., Chelan, Washington.

20. Steig, T.W., J.W. Horchik, and G.W. Tritt. 2002. Monitoring Juvenile Chinook Salmon Migration Routes With Acoustic Tags in the Forebay of Rock Island Dam During 2001. Final Report. Chelan County Public Utility District No. 1, Wenatchee, WA.*

21. Steig, T.W., P. A. Nealson, K. K. Kumagai, L. S. Brown, G.W. Tritt, K.C. Molitor, J. W. Horchik, M.A. Timko, J.C. Sweet, and C. P. Mott. 2006. Route Specific Passage of Juvenile Steelhead, Chinook, and Sockeye Salmon Using Acoustic Tag Methodologies at Rocky Reach and Rock Island Dams in 2005. Report Prepared for Chelan County PUD No. 1, Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

22. Steig, T.W., P.A. Nealson, K.K. Kumegai, J.W. Horchik, C.P. Mott, and J.C. Sweet. 2006. Route Specific Passage of Juvenile Chinook, Steelhead, and Sockeye Salmon Using Acoustic Tag

Methodologies at Rocky Reach and Rock Island Dams in 2004. Report Prepared for Chelan County PUD No. 1, Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

23. Stevenson, J.R., A.E. Giorgi, W.R Koski, K.K English, and C.A. Grant. 1997. Evaluation of Juvenile Spring Chinook and Steelhead Migratory Patterns at Rocky Reach and Rock Island Dams Using Radio Telemetry Techniques, 1996. Report Prepared for Chelan County PUD No. 1 Wenatchee, Washington. BioAnalysts, Inc., Redmond, Washington.*

24. Stevenson, J.R., J.R. Skalski, P. Westhagen, and A.E. Giorgi. 2004. Fish Passage Efficiency of Juvenile Yearling and Subyearling Chinook, Steelhead and Sockeye at Rocky Reach and Rock Island Dams, 2003: Telemetry Investigation. Chelan County PUD, Wenatchee, Washington.*

D.1.3.3 Rock Island: Physical Modeling

1. Haug, P. E. and J.A. Odgaard. 2004. Hydraulic Model Studies for Fish Passage through an Overflow-Underflow Gate Combination at Rock Island Dam. IIHR Limited Distribution Report No. 320. July 2004.

2. Mih, W. S. 1983. Hydraulic Model Studies of Submerged Traveling Screens at Rock Island and Rocky Reach Dams. R. L. Albrook Hydraulics Laboratory, Pullman, WA. 1983

3. Odgaard, J. A. 1992. Hydraulic Model Study for Fish Guidance System for First Powerhouse of the Rock Island Project. IIHR Limited Distribution Report No. 203. November 1992.

D.1.3.4 Rock Island: Multidisciplinary

1. Carlson, T. J., and J.P. Duncan. 2002. Characterization of the Hydraulic Environment Experienced by Fish Passage in Spill at Rock Island Dam, 2001. Prepared by Battelle, Pacific Northwest Division for Public Utility District No. 1 of Chelan County.

2. District Staff, et. al. 1995. Rocky Reach Dam and Rock Island Dam Fish Bypass Annual Project Team Report for Period Ending December 1994. Summary Report Prepared for Public Utility District No. 1 of Chelan County, Washington.*

3. Nielsen, K. D. 1999. Letter report to Mr. Tracy Yount of Public Utility District No. 1 of Chelan County, Wenatchee, Wash., dated March 19, 1999

4. Oakwood Consulting Inc. 2006. Summary of Hydraulic and Fish Passage Characteristics for Top-Spill Bypasses at Rock Island, Wanapum and Priest Rapids Dams. Report Submitted to U.S. Army Corps of Engineers Walla Walla District. Oakwood Consulting Inc, Belcarra, BC, Canada.*

D.1.4 Wanapum Reference List

D.1.4.1 Wanapum: Engineering Design

1. Chapman, D.W. 1988. Bypass Options at Wanapum and Priest Rapids Dam. Don Chapman Consultants, Inc., Boise, ID.

2. Iowa Institute of Hydraulic Research (IIHR), A.J. Odgaard, M.P. Cherian, and R.A. Elder. Fish Diversion at Wanapum Development Grant County PUD. Report Prepared for Grant County Public Utility District, Ephrata, WA. University of Iowa, Iowa Institute of Hydraulic Research, Iowa City, Iowa.

3. Reid, N. and B. Hughes. 2004. Letter Report prepared by Northwest Hydraulic Consultants dated May 13, 2004.

4. Sverdrup Corporation and Hydroacoustic Technology Inc. 1995. Attraction Flow Prototype for Wanapum Dam, 1995 Study Plan, Final Report. Sponsored by Grant County Public Utility District No. 2, Ephrata, WA. Sverdrup Corporation and Hydroacoustic Technology Inc., Kirkland and Seattle, WA.

5. Weber, L. J., Odgaard, A. J., and Elder, R. (1994). Study of the Effect of Withdrawal from a Vertical Slot Located Above a Turbine Intake on the Near Surface Velocities. IIHR Limited Distribution Report No. 221.

6. Weitkamp, D.E. and R.A. Elder. 1994. Recommendations for Fish Bypass Outfall Location, Wanapum Dam. Prepared for Grant County Public Utility District, Kirkland, WA. Parametrix, Inc.*

D.1.4.2 Wanapum: Biological Evaluation

1. Birmingham, A. G., B.H. Ransom, H. Charvet, and B.A. Schnebly. Run Timing of Juvenile Salmon and Steelhead Trout Passage at Wanapum Dam During Summer 1996. 1997. Hydroacoustic Technology. June 6, 1997.

2. Birmingham, A. G., B.H. Ransom, G.W. Tritt, and H. Charvet. Run Timing of Juvenile Salmon and Steelhead Trout Passage at Wanapum Dam During Spring 1997. 1997. Hydroacoustic Technology, Inc. December 18. 1997.

3. BioSonics, Inc. 1985. Hydroacoustic Assessment of Downstream Migrating Salmon and Steelhead at Wanapum Dam in 1984, Draft. Report Prepared for Grant County PUD No. 2, Ephrata, WA. BioSonics, Inc., Seattle, WA.

4. Goodwin, R.A., J.M. Nestler, J.J. Anderson, J. Kim, and T. Toney. 2005. Evaluating Wanapum Dam Bypass Configurations for Outmigrating Juvenile Salmon Using Virtual Fish: Numerical Fish Surrogate (NFS) Analysis. U.S. Army Engineer Research & Development Center, Waterways Experiment Station, Vicksburg, Mississippi 39180-6199. ERDC/EL TR-05-7.

5. Weber, L. J., Goodwin, R. A., Li, S., Nestler, J. M., and Anderson, J. J. (2006). "Application of an Eulerian–Lagrangian–Agent method (ELAM) to rank alternative designs of a juvenile fish passage facility." Journal of Hydroinformatics, 8(4), 271–295.

6. Hydroacoustic Technology, Inc. (HTI), K.K. Kumagai, R.L. Evenson, B.H. Ransom, and H. Charvet. 1998. Hydroacoustic Evaluation of Juvenile Salmon and Steelhead Trout Vertical Distributions in Wanapum Dam Forebay During Spring and Summer 1997. Final Report Volume 2 of 2. Report Prepared for Grant County Public Utility District No. 2, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.

7. Kumagai, K.K., B.H. Ransom, and H.A. Sloan. 1996. Effectiveness of a Prototype Surface Flow Attraction Channel for Passing Juvenile Salmon and Steelhead Trout at Wanapum Dam During Summer 1996. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc. Seattle, WA.*

8. Kumagai, K.K., B.H. Ransom, H.A. Sloan, and H. Charvet. 1997. Effectiveness of a Prototype Surface Flow Attraction Channel for Passing Juvenile Salmon and Steelhead Trout at Wanapum Dam During Spring 1997. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology Inc. Seattle, WA.*

9. Kumagai, K.K., R.L. Evenson, B.H. Ransom, and H. Charvet. 1998. Hydroacoustic Evaluation of Juvenile Salmon and Steelhead Trout Vertical Distributions in Wanapum Dam Forebay During Spring and Summer 1997. Final Report Volume 1 of 2. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.

10. Nealson, P.A., R.L. Evenson, and K.K. Kumagai. 1997. Fish Distributions and Trajectories in The Wanapum Dam Forebay During 1996. Prepared for Grant County Public Utility District. Hydroacoustic Technology, Inc., Seattle, WA.*

11. Normandeau Associates and J.R. Skalski. 2002. Evaluation of Smolt Mortality and Injury Associated With Passage Through A Modified Top Spill Bulkhead Spillway at Wanapum Dam, Columbia River. Report Prepared for Grant County PUD No. 2, Ephrata, Washington. Normandeau Associates, Inc. Drumore, PA.*

12. Normandeau Associates, Inc., Parametrix, Inc., and J.R. Skalski. 1996. Behavior of Juvenile Salmonids Relative to the Prototype Surface Bypass Collection Channel at Wanapum Dam, Columbia River, Washington. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Normandeau Associates, Inc., Drumore, PA.*

13. Normandeau Associates, Inc., J.R. Skalski, and Mid Columbia Consulting Inc. 1996a. Fish Survival in Passage through the Spillway and Sluiceway at Wanapum Dam on the Columbia River, Washington. December 1996.

14. Normandeau Associates, Inc., Parametrix, Inc., and J.R. Skalski. 1998. Response of Salmonid Smolts to a Prototype Surface Collector at Wanapum Dam, and Smolt Movement and Behavior at Priest Rapids Dam, Columbia River, Washington. Normandeau Associates, Inc., Drumore, PA.*

15. Normandeau Associates, Inc. and J. Skalski. 2003. Evaluation of Smolt Mortality and Injury Associated with Passage Through a Modified Top Spill Bulkhead Spillway at Wanapum Dam, Columbia River.

16. Normandeau Associates, Inc., and Battelle. 2005. Estimation of Direct Survival and Condition of Juvenile Salmonids Passed by a Prototype Bypass Sluice Chute at Wanapum Dam, Columbia River, Washington. January 2005.

17. Ransom, B.H. 1997. Summary of Spillway and Sluiceway Effectiveness in Passing Juvenile Salmonid at Wanapum and Priest Rapids Dams From 1980-1996. Prepared for Grant County Public Utility District. Hydroacoustic Technology, Inc., Seattle, WA.*

18. Ransom, B.H., B.D. McFadden, and B.A. Schnebly. 1991. Hydroacoustic Evaluation of the Effectiveness of the Sluiceway at Wanapum Dam in Passing Juvenile Salmon and Steelhead Trout During Spring 1991. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

19. Ransom, B.H., K.K. Kumagai, A.G. Birmingham, K.A. Divens, and P.A. Nealson. 1996. Effectiveness of a Prototype Surface Flow Attraction Channel for Passing Juvenile Salmon and Steelhead Trout at Wanapum Dam During Spring and Summer 1995. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA. *

20. Ransom, B.H., K.K. Kumagai, B.A. Schnebly, and A.G. Birmingham. 1998. Hydroacoustic Evaluation of Prototype in-Turbine Diversion Screens for Subyearling Chinook Salmon at Wanapum Dam During Summer 1994. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

21. Ransom, B.H. and K.M. Malone. 1990. Hydroacoustic Evaluation of the Effectiveness of the Sluiceway at Wanapum Dam in Passing Juvenile Salmon and Steelhead Trout During Spring 1990, Draft. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

22. Robichaud, D., K.K. English, C. Sliwinski, B. Nass, A. Blakley, and C. Grant. 2002. Telemetric Assessment of Chinook Smolt Behavior in Relation to Various Spill Methods at Wanapum and Priest Rapids Dams, 2002. Draft C. Grant County PUD No.2, Ephrata, WA.

23. Robichaud, D., K.K. English, J.R. Skalski, B.L. Nass, J. Lady, C. Sliwinski, and A. Blakley. 2003. Survival of Chinook Smolts During Various Spill Configurations at Wanapum and Priest Rapids Dams, 2002, Draft A. Report Prepared for Grant County PUD No. 2, Ephrata, WA. LGL Limited, Sidney, BC, Canada.

24. Robichaud, D., B. Nass, M.A. Timko, K.K. English, and B. Ransom. 2005. Analysis of Chinook Smolt Behavior and Relative Survival at Wanapum Dam Using Three-Dimensional Acoustic-Telemetry 2004. LGL Limited Environmental Research Associates and Hydroacoustic Technology, Inc., 2 November 2005.

25. Robichaud, D., B. Nass, M.A. Timko, K.K. English, B. Ransom, and G. Tritt. 2005a. Analysis of Sockeye and Steelhead Smolt Behavior at Wanapum Dam Using Three-Dimensional Acoustic-Telemetry, 2004. LGL Limited Environmental Research Associates and Hydroacoustic Technology, Inc., 2 November 2005.

26. Skalski, J.R., Normandeau Associates, and Mid-Columbia Consulting. 1996. Fish Survival in Passage Through the Spillway and Sluiceway at Wanapum Dam on the Columbia River, Washington. Report Prepared for Grant County PUD No. 2, Ephrata, Washington. Columbia Basin Research, School of Fisheries, University of Washington, Seattle, Washington.*

27. Voskuilen, M. 1995. Wanapum Dam Attraction Flow Prototype Design Considerations: A Review of the 1981 to 1992 Hydroacoustic Studies of the Wells Dam Juvenile Fish Bypass System. Report Prepared for Public Utility District No. 2 of Grant County. Sverdrup Corporation.*

D.1.4.3 Wanapum: Numerical Modeling

1. Li, S. and L.J. Weber. 2006. A Comparison of Hydrodynamic Parameters Associated with Various Fish Passage Routes at Wanapum Dam. IIHR Limited Distribution Report No. 334. March 2006.

2. Li, S. and L.J. Weber. 2006a. Comprehensive Comparison of the Three-Dimensional Computational Fluid Dynamics (CFD) Model Outputs with Field Data of the Wanapum Dam Forebay and Tailrace. IIHR Limited Distribution Report No. 335. April 2006.

3. Li, S. and L.J. Weber. 2006b. Three-Dimensional (3-D) Computational Fluid Dynamics (CFD) Modeling of Fish Passage through Various Bypass Routes at Future Units of Wanapum Dam. IIHR Limited Distribution Report No. 336. April 2006.

4. Li, S. and L.J. Weber. 2006c. Three-Dimensional Computational Fluid Dynamics Modeling of Fish Passage Through Various Bypass Routes at Wanapum Dam: for Numerical Fish Surrogate Analysis, Fish Passage Radio-Telemetry Studies, and Future Unit Concept Assessment. IIHR Limited Distribution Report No. 339. June 2006.

D.1.4.4 Wanapum: Physical Modeling

1. Lyons, C. T., Haug, P. E., Carrica, P. M., and Weber, L. J. (2005). Hydraulic Model Studies for Fish Diversion at Wanapum/Priest Rapids Development. Part XXII: Model Studies of a Future Unit Fish Bypass for Wanapum Dam. IIHR Limited Distribution Report No. 325. May 2005.

2. Mannheim, C., and L.J. Weber. 1997. Hydraulic Model Studies for Fish Diversion at Wanapum/Pries Rapids Development. Part XIII: Physical Modeling of Wanapum Spillway Bulkhead. IIHR Limited Distribution Report No 266.

D.1.4.5 Wanapum: Multidisciplinary

1. BioSonics, Inc. 1982. Preliminary Results: 1982 Spill Effectiveness Study at Wanapum Dam. Report Prepared for Grant County PUD No. 2, Ephrata, WA. BioSonics, Inc., Seattle, WA.

2. CH2M Hill and Washington Department of Fisheries (WDF). 1980. Evaluation of The Effectiveness of Water Spilling for Passage of Juvenile Salmon at Wanapum Dam. Report Prepared for Grant, Douglas and Chelan County Public Utility Districts. CH2M-Hill.

3. Haug, P. E., Li, Songheng, Weber, L.J. Hydraulic Model Study for Fish Diversion at Wanapum/Priest Rapids Development. Part XVII: Summary of Hydraulic and CFD Models for Wanapum Dam. IIHR Limited Distribution Report No. 310. January 2003.

4. Jacobs Civil Inc., Grant County PUD, Oakwood Consulting Inc., NOAA Fisheries, and IIHR Hydroscience and Engineering. 2004. Design Team Plan for Development of Downstream Fish Passage Measures at Wanapum Dam 2003-2004.*

5. Mannheim, C. and L.J. Weber. 1997. Hydraulic Model Studies for Fish Diversion at Wanapum/Priest Rapids Development Part XIII: Physical Modeling of Wanapum Spillway Bulkhead. Prepared for Public Utility District No 2 of Grant County, Ephrata, Washington. Iowa Institute of Hydraulic Research, Iowa City, IA. IIHR Limited Distribution Report No. 266.

6. Oakwood Consulting Inc. 2006. Summary of Hydraulic and Fish Passage Characteristics for Top-Spill Bypasses at Rock Island, Wanapum and Priest Rapids Dams. Report Submitted to U.S. Army Corps of Engineers Walla Walla District. Oakwood Consulting Inc, Belcarra, BC, Canada.*

7. Oakwood Consulting Inc. 2005. Wanapum Dam Future Unit Fish Bypass Hydraulic Design Summary Report. Prepared For Public Utility District No. 2 of Grant County. Oakwood Consulting, Belcarra, BC, CA.*

8. Ransom, B. H., K.K. Kumagai, A.G. Birmingham, K.A. Divens, and P.A. Nealson. 1996. Effectiveness of a Prototype Surface Flow Attraction Channel for Passing Juvenile Salmon and Steelhead Trout at Wanapum Dam during Spring and Summer 1995. Hydoacoustic Technology, Inc. December 12, 1996.

D.1.5 Priest Rapids Reference List

D.1.5.1 Priest Rapids: Engineering Design

1. Chapman, D.W. 1988. Bypass Options at Wanapum and Priest Rapids Dam. Don Chapman Consultants, Inc., Boise, ID.

2. Weitkamp, D.E. and D. Hay. 1996. Recommendations for Fish Bypass Outfall Location, Priest Rapids Dam. Parametrix, Inc. and Hay & Company for Grant County Public Utility District, Kirkland, WA.*

D.1.5.2 Priest Rapids: Biological Evaluation

1. Anglea, S.M., C.S. McCutcheon, J.R. Skalski, R.J. Richmond, and R.L. Townsend. 2003. Survival of PIT-Tagged Yearling Chinook Salmon Passage Through The Priest Rapids Project, 2003. Prepared for Public Utility District No. 2 of Grant County, Ephrata, WA. Battelle.

2. Grant County Public Utility District. 1982. 1982 Spill Effectiveness Study at Priest Rapids Dam. Grant County Public Utility District, Ephrata, WA.

3. McFadden, B.D., B.H. Ransom, and B.A. Schnebly. 1993. Hydroacoustic Evaluation of the Effectiveness of the Sluiceway at Priest Rapids Dam in Passing Juvenile Salmon and Steelhead Trout During Spring and Summer 1992. Report Prepared for Grant County Public Utility District, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.*

4. Normandeau Associates, Inc., Parametrix, Inc., and J.R. Skalski. 1998. Response of Salmonid Smolts to a Prototype Surface Collector at Wanapum Dam, and Smolt Movement and Behavior at Priest Rapids Dam, Columbia River, Washington. Normandeau Associates, Inc., Drumore, PA.*

5. Ransom, B.H. 1997. Summary of Spillway and Sluiceway Effectiveness in Passing Juvenile Salmonid at Wanapum and Priest Rapids Dams From 1980-1996. Prepared for Grant County Public Utility District. Hydroacoustic Technology, Inc., Seattle, WA.*

6. Ransom, B.H. and K.M. Malone. 1989. Hydroacoustic Evaluation of a Forebay Wedge Screen for Diverting Juvenile Salmon and Steelhead Trout at Turbine Intakes at Priest Rapids Dam, 1989. Hydroacoustic Technology, Inc. and Grant County Public Utility District No. 2, Contract No. 430-366 (Tasks 1 and 2), Seattle, WA and Ephrata, WA.

7. Robichaud, D., K.K. English, C. Sliwinski, B. Nass, A. Blakley, and C. Grant. 2002. Telemetric Assessment of Chinook Smolt Behavior in Relation to Various Spill Methods at Wanapum and Priest Rapids Dams, 2002. Draft C. Grant County PUD No.2, Ephrata, WA.

8. Robichaud, D., K.K. English, J.R. Skalski, B.L. Nass, J. Lady, C. Sliwinski, and A. Blakley. 2003. Survival of Chinook Smolts During Various Spill Configurations at Wanapum and Priest Rapids Dams, 2002, Draft A. Report Prepared for Grant County PUD No. 2, Ephrata, WA. LGL Limited, Sidney, BC, Canada.

D.1.5.3 Priest Rapids: Multidisciplinary

1. Jacobs, IIHR, and Oakwood Consulting Inc. 2003. Fish Passage Alternatives Study for the Priest Rapids Project. January 31, 2003.

2. Mannheim, C. and L.J. Weber. 1997. Hydraulic Model Studies for Fish Diversion at Wanapum/Priest Rapids Development Part XIII: Physical Modeling of Wanapum Spillway Bulkhead. Prepared for Public Utility District No 2 of Grant County, Ephrata, Washington. Iowa Institute of Hydraulic Research, Iowa City, IA. IIHR Limited Distribution Report No. 266.

3. Marquette, W.M. and C.W. Long. 1971. Laboratory Studies of Screens for Diverting Juvenile Salmon and Trout From Turbine Intakes. *Transactions of the American Fisheries Society*. 100(3):439-447.

4. Oakwood Consulting Inc. 2006. Summary of Hydraulic and Fish Passage Characteristics for Top-Spill Bypasses at Rock Island, Wanapum and Priest Rapids Dams. Report Submitted to U.S. Army Corps of Engineers Walla Walla District. Oakwood Consulting Inc, Belcarra, BC, Canada.*

5. Voskuilen, M., et al. 2003. Fish Passage Alternatives Study at the Priest Rapids Project. Report Prepared for Public Utility District No. 2 of Grant County. Jacobs Engineering, Bellevue, WA, Iowa Institute of Hydraulic Research, Iowa City, IA and Oakwood Consulting, Vancouver, BC.

D.2 Lower Snake River Reference List

D.2.1 Lower Granite Reference List

D.2.1.1 Lower Granite: Engineering Design

1. CH2M Hill. 1997. Lower Granite Dam Behavioral Guidance Structure: Preliminary Design Report.*

2. CH2M Hill. 2000. Lower Granite Surface Bypass and Collection, Behavioral Guidance Structure Modifications for 2001 Test. Feasibility Report and Documentation. Prepared for USACE Walla Walla District.*

3. CH2M Hill. 2003. Lower Granite Lock and Dam, Modified BGS 2004 Prototype Hydraulic Design Document Report.*

4. HDR and ENSR. 2000. Documentation of Hydrodynamic Conditions and Project Operation. Lower Granite Surface Bypass and Collector 2000 Prototype Tests. Prepared for USACE, Walla Walla District.*

5. Stone & Webster. 1995. Conceptual Design of 1997 Lower Granite Surface Bypass and Collection System. Development and Evaluation, Preliminary SBCS Alternatives. Prepared for USACE, Walla Walla District.*

6. Stone & Webster. 1995. Conceptual Design of 1997 Lower Granite Surface Bypass and Collection System. Final Conceptual Design Report. Prepared for USACE, Walla Walla District.*

7. Stone & Webster. 1995. Conceptual Design of Lower Granite Surface Bypass and Collection System. Evaluation of Advanced Alternatives. Final Report. Prepared for USACE, Walla Walla District.*

8. Sverdrup and ENSR. 1998. Lower Snake River Surface Bypass and Collection System Combinations Conceptual Design Report. Final report.

9. Sverdrup and ENSR. 1998. Lower Granite Lock and Dam: Surface Bypass and Collection System Options Conceptual Design Report.

10. Sverdrup, ENSR, Lund Engineering, and The Glosten Associates. 2000. Lower Granite Lock and Dam Surface Bypass and Collection Removable Spillway Weir. Pre-engineering report.*

11. Sverdrup, ENSR, Lund Engineering, and The Glosten Associates. 2000. Lower Granite Removable Spillway Weir Decision Documentation Report. Submitted to USACE, Walla Walla District.*

12. Sverdrup Corporation, ENSR, and Hamilton Engineering, Inc. 1998. Lower Granite Lock and Dam Surface Bypass and Collection System Options Conceptual Design Report. Final Report. U.S. Army Corps of Engineers, Walla Walla, Washington.*

13. U.S. Army Corps of Engineers. 2000. Discharge and Velocity Measurements in Surface Bypass and Collector. Lower Granite Lock and Dam. USACE Walla Walla District, Walla Walla, WA.*

D.2.1.2 Lower Granite: Biological Evaluation

1. Adams, N., G. Johnson, D. Rondorf, S. Anglea, and T. Wik. 2001. Biological Evaluation of the Behavioral Guidance Structure at Lower Granite Dam on the Snake River, Washington in 1998. *American Fisheries Society Symposium*. 26.*

2. Adams, N.S. and D.W. Rondorf. 2001. Juvenile Chinook Salmon and Steelhead Passage in the Forebay of Lower Granite Dam Relative to Surface Bypass Collector and Behavioral Guidance Structure Tests. Annual Report for 1998. Prepared for U.S. Army Corps of Engineers, Walla Walla District, Washington. U.S. Geological Survey, Cook, Washington.

3. Adams, N.S. and D.W. Rondorf. 1998. Migrational Characteristics of Juvenile Fall Chinook Salmon in the Forebay of Lower Granite Dam Relative to 1998 Surface Bypass Collector Tests.

4. Adams, N.S. and D.W. Rondorf. 1998. Migrational Characteristics of Juvenile Spring and Fall Chinook Salmon and Steelhead in the Forebay of Lower Granite Dam Relative to the 1999 Surface Collector/Bypass Tests. Draft. U.S. Geological Survey. Cook, Washington.

5. Adams, N.S., D.W. Rondorf, E.E. Kofoot, M.J. Banach, and M.A. Tuell. 1997. Migrational Characteristics of Juvenile Chinook Salmon and Steelhead in the Forebay of Lower Granite Dam Relative to the 1996 Surface Bypass Collector Tests. Annual report 1996 prepared for U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

6. Adams, N.S., D.W. Rondorf, and M.A. Tuell. 1998. Migrational Characteristics of Juvenile Spring and Fall Chinook Salmon and Steelhead in the Forebay of Lower Granite Dam Relative to the 1997 Surface Bypass Collector Tests. Final report for 1997. Prepared for U.S. Army Corps of Engineers, Walla Walla District, Washington.

7. Adams, N.S., D.W. Rondorf, N.M. Tuell, and M.J. Banach. 1995. Migrational Characteristics of Juvenile Spring Chinook Salmon and Steelhead in Lower Granite Reservoir and Tributaries, Snake River. Final Report to the U.S. Army Corps of Engineers, Contract E-86930151. USGS.

8. Adams, N.S. and six co-authors from American Fisheries Society. 1999. Migrational Characteristics of Radio-Tagged Juvenile Salmonids During Operation of a Surface Collection and Bypass System. Pages 105-118 In M. Odeh (Ed.) Innovations in Fish Passage Technology. USGS.

9. Anglea, S.M., K.D. Ham, G.E. Johnson, M.A. Simmons, C.S. Simmons, E. Kudera, and J. Skalski. 2003. Hydroacoustic Evaluation of the Removable Spillway Weir at Lower Granite Dam in 2002. Final. PNWD-3219.*

10. Anglea, S.M., R.L. Johnson, M.A. Simmons, K.D. Hand, E.A. Kudera, and J.R. Skalski. 2000. Hydroacoustic Evaluation of the Prototype Surface Bypass/Collector and Behavioral Guidance Structure at Lower Granite Dam in 1999. Final Report to U.S. Army Corps of Engineers, Walla Walla District, Washington.

11. Anglea, S.M., et al. 2000. Fixed-Location Hydroacoustic Evaluation of the Prototype Surface Bypass and Collector at Lower Granite Dam in 2000, Final Report. Battelle.

12. Bennett, D.H. and G.P. Naughton. 1999. Predator Abundance and Salmonid Prey Consumption in Tailrace and Forebay of Lower Granite Dam. Completion Report. Project 14-15-0009-1579. University of Idaho, Idaho.

13. Cash, K. and five co-authors. 2005. Three-Dimensional Fish Tracking to Evaluate the Removable Spillway Weir at Lower Granite Dam During 2003. Final Report Prepared for the Walla Walla

District, U.S. Army Corps of Engineers. USGS.*

14. Cash, K.M., N.S. Adams, T.W. Hatton, E.C. Jones, and D.W. Rondorf. 2002. Three-Dimensional Fish Tracking to Evaluate the Operation of the Lower Granite Surface Bypass Collector and Behavioral Guidance Structure During 2000. Annual Report of research, 2000. US Geological Survey.

15. Cash, K.M., T.W. Hatton, E.C. Jones, R.J. Magie, K.C. Mayer, N.M. Swyers, N.S. Adams, and D.W. Rondorf. 2003. Three-Dimensional Fish Tracking to Evaluate the Removable Spillway Weir at Lower Granite Dam During 2002. Draft.

16. Dauble, D., S. Anglea, and G. Johnson. 1999. Surface Flow Bypass Development in the Columbia and Snake Rivers and Implications Related to Research at Lower Granite Dam. Final report submitted to Walla Walla District, U.S. Army Corps of Engineers. July 21, 1999.

17. Dawson, J., M. Burger, and M. Dinsmore. 2006. Hydroacoustic Evaluation of Fish Passage at Lower Granite Dam Associated With the Prototype Removable Spillway Weir, 2005. Final Report Prepared for the Walla Walla District, U.S. Army Corps of Engineers. BioSonics, Inc.*

18. Goodwin, R.A. 2004. Hydrodynamics and Juvenile Salmon Movement Behavior at Lower Granite Dam: Decoding the Relationship Using 3-D Space-Time (CEL Agent IBM) Simulation. PhD Dissertation, Cornell University, Ithaca, NY.

19. Johnson, G.E., N.S. Adams, R.L. Johnson, D.W. Rondorf, D.D. Dauble, and T.Y. Barila. 2000. Evaluation of the Prototype Surface Bypass for Salmonid Juvenile Salmonids in Spring 1996 and 1997 at Lower Granite Dam on the Snake River, Washington. Trans. Am. Fish. Soc. 129: 381-397.*

20. Johnson, G.E. and D.D. Dauble. 1995. Synthesis of Existing Physical and Biological Information Relative to Development of a Prototype Surface Flow Bypass System at Lower Granite Dam. Final report. Submitted to CENWW, Walla Walla, Wa. PNNL.*

21. Johnson, G.E. and nine co-authors. 1998. Fixed-Location Hydroacoustic Evaluation of the Prototype Surface Bypass and Collector, Spill Efficiency, and Fish Guidance Efficiency at Lower Granite Dam in Spring and Summer 1997. Final Report. Contract No. DACW68-96-D-0002. Battelle's Pacific Northwest. PNNL.

22. Johnson, G.E., R.L. Johnson, E. Kudera, and C. Sullivan. 1997. Fixed-Location Hydroacoustic Evaluation of the Prototype Surface Bypass and Collector at Lower Granite Dam in 1996. Final Report. Contract No. DACW68-96-D-0002. PNNL.

23. Johnson, G.E., R.L. Johnson, N.S. Adams, and D.W. Rondorf. 1997. Integration of Research on the Prototype Surface Bypass and Collector at Lower Granite Dam in 1996 and 1997. Completion Report. U.S. Army Corps of Engineers, Walla Walla, Washington.

24. Johnson, G.E., S.M. Anglea, N.S. Adams, and T.O. Wik. 2005. Evaluation of The Prototype Surface Flow Bypass for Juvenile Salmon and Steelhead at The Powerhouse of Lower Granite Dam, Snake River, Washington, 1996-2000. *N. Amer. J. Fish. Management*. 25.*

25. Johnson, R. and G. Johnson. 2000. Fish Behavior Relative to A Prototype Surface Bypass and Collector (SBC) at Lower Granite Dam, Using Innovative Hydroacoustic Techniques. Battelle.

26. Johnson, R.L. and 8 others. 1999. Hydroacoustic Evaluation of Fish Passage and Behavior at Lower Granite Dam in Spring 1998. Summary report. PNWD-2448.

27. Kudera, E.A. and C.M. Sullivan. 1996. Hydroacoustic Monitoring of Smolt Passage at Lower Granite Dam in 1995. Final Report. Contract No. DACW68-95-C-0027. BioSonics, Inc.

28. Mathur D., P. Heisey, J. Skalski, and D. Kenney. 1999. Survival of Chinook Salmon Smolts Through the Surface Bypass Collector at Lower Granite Dam, Snake River. Editor: M. Odeh. Innovations in Fish Passage Technology. American Fisheries Society, Bethesda, MD. Pages 119-128.

29. Normandeau Associates, Inc., J.R. Skalski, and Mid Columbia Consulting, Inc. 1996. Evaluation of Chinook Salmon Smolt (*Oncorhynchus Tshawytscha*) Survival and Condition Associated With Passage Through The Surface Bypass Collector at Lower Granite Dam, Snake River. U.S. Army Corps of Engineers, Walla Walla, Washington. Contract No. DACW-68-96-D-003.

30. Normandeau Associates, Inc., J.R. Skalski, and Mid Columbia Consulting, Inc. 2002. Passage Survival and Fish Condition at the Removable Spillway Weir at Lower Granite Dam, Snake River. Final.*

31. Normandeau Associates, Inc., J.R. Skalski, and Mid Columbia Consulting Inc. 2000. Passage Survival and Fish Condition at the Surface Bypass/Collector at Lower Granite Dam 2000. Final Report. Contract No. DACW68-96-D-0003.

32. Piaskowski, R., P. Keniry, and T. Bjornn. 1998. Distribution and Movements of Northern Squawfish and Smallmouth Bass During Operation of a Surface Bypass and Collection System for Juvenile Salmonids Lower Granite Dam, WA. Presentation at Annual Research Review for the Anadromous Fish Evaluation Program. Portland, Oregon.

33. Plumb, J. and ten co-authors. 2004. Behavior and Survival of Radio-Tagged Juvenile Chinook Salmon and Steelhead Relative to the Performance of a Removable Spillway Weir at Lower Granite Dam, Washington, 2003. Final Report of Research Submitted to CENWW. USGS.*

34. Plumb, J.M., A.C. Braatz, J.N. Lucchesi, S.D. Fielding, J.M. Sprando, G.T. George, N.S. Adams, and D.W. Rondorf. 2003. Behavior of Radio-Tagged Juvenile Chinook Salmon and Steelhead and Performance of a Removable Spillway Weir at Lower Granite Dam, Washington, 2002. Draft. W68SBV00104592.*

35. Plumb, J.M., M.S. Novick, A.C. Braatz, J.N. Lucchesi, J.M. Sprando, N.S. Adams, and D. Rondorf. 2002. Behavior and Migratory Delay of Radio-Tagged Juvenile Spring Chinook Salmon and Steelhead Through Lower Granite Dam and Reservoir During a Drought Year. U.S. Geological Survey.

36. Plumb, J.M., M.S. Novick, N.S. Adams, and D.W. Rondorf. 2002. Behavior of Radio-Tagged Juvenile Chinook Salmon and Steelhead in the Forebay of Lower Granite Dam Relative to the 2000 Surface Bypass and Behavioral Guidance Structure Tests. Annual Report of Research, 2000. U.S. Geological Survey.

37. Tuell, M.A. and S.R. Everett. 1998. Forebay Mobile Telemetry Relative to 1996-1998 Surface Bypass Collector/Behavioral Guidance Structure Tests at Lower Granite Dam. 1996-1998 draft final report. Prepared for U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

38. U.S. Army Corps of Engineers, Walla Walla District. 1996. Evaluation of The Prototype Surface Bypass and Collector at Lower Granite Dam in 1996: Integration of Preliminary Research Findings. Draft.

D.2.1.3 Lower Granite: Numerical Modeling

1. Nestler, J.M., R.A. Goodwin, and R.S. Chapman. 2000. Development of a Numerical Fish Surrogate for Improved Selection of Fish Passage Design and Operation Alternatives for Lower Granite Dam: Phase I. U.S. Army Engineer Research & Development Center, Waterways Experiment Station, Vicksburg, Mississippi 39180-6199. ERDC/EL TR-00-12.

2. Goodwin, R. A., Nestler, J. M., Anderson, J. J., and Weber, L. J. (2004). "Virtual fish to evaluate bypass structures for endangered species." Proceedings of the 5th International Symposium on Ecohydraulics, 12 – 17 September 2004, Madrid, Spain.

3. Goodwin, R. A., Nestler, J. M., Anderson, J. J., and Weber, L. J. (2004). "Forecast simulations of 3-D fish response to hydraulic structures." Proceedings of the World Water & Environmental Resources Congress, American Society of Civil Engineers, 27 June – 1 July 2004, Salt Lake City, Utah.

D.2.1.4 Lower Granite: Physical Modeling

1. Davidson, R.A. 1989. Lower Granite Fish Guidance Efficiency Study, Snake River, WA. Hydraulic Modeling Investigation. Miscellaneous Paper HL-89-1. Prepared for USACE, Walla Walla District. WES, Vicksburg, MS.

2. ENSR and Sverdrup. 2000. Hydraulic Model Study of Removable Spillway Weir for Juvenile Fish Passage at Lower Granite Dam. Final Report. Prepared for U.S. Army Corps of Engineers Walla Walla District. ENSR document no. 6455-023-460.*

D.2.1.5 Lower Granite: Multidisciplinary

1. Anglea, S.M., G.E. Johnson, T.O. Wik, L.A. Reese, and A.E. Giorgi. 2002. Development of the Surface Bypass and Collector for Juvenile Salmon and Steelhead at Lower Granite Dam, 1994-2000. Final report submitted to U.S. Army Corps of Engineers, Walla Walla District.*

2. Darland, T.J., B.J. Hausmann, C.D. Smith, D.H. Rondorf, J.D. Seril, and C.F. Morrill. 2000. Testing Behavioral Technologies in Conjunction With the Surface Bypass Program at Lower Granite Dam: Directed Flow Evaluation. USGS.

D.2.2 Lower Monumental Reference List

D.2.2.1 Lower Monumental: Biological Evaluation

1. Johnson, G.E., R.A. Morsund, and J.R. Skalski. 1998. Fixed-Location Hydroacoustic Evaluation of Spill Effectiveness at Lower Monumental Dam in 1997. Battelle, Richland, WA.

2. McFadden, B.D. 1988. Hydroacoustic Evaluation of Juvenile Fish Passage at Lower Monumental Dam in 1988. U.S. Army Corps of Engineers, Walla Walla, Washington.

3. Parametrix, Inc. and Associated Fisheries Biologists, Inc. 1986. Hydroacoustic Evaluation of Juvenile Fish Passage at Lower Monumental Dam in Spring 1986. Draft report.

4. Smith, J.R. 1974. Distribution of Seaward-Migrating Chinook Salmon and Steelhead Trout in the Snake River Above Lower Monumental Dam. Marine Fisheries Review 36(8): 42-45.*

D.2.2.2 Lower Monumental: Physical Modeling

1. ENSR. 2005. Hydraulic Model Study of Removable Spillway Weir for Juvenile Fish Passage at Lower Monumental Dam. 90% Report. Prepared for U.S. Army Corps of Engineers Walla Walla District. ENSR document no. 09000-365-2720.*

D.2.3 Ice Harbor Reference List

D.2.3.1 Ice Harbor: Engineering Design

1. Jacobs Civil, Inc. 2004. Design Documentation Report, BCOE Submittal. Prepared for U.S. Army Corps of Engineers Walla Walla District.*

D.2.3.2 Ice Harbor: Biological Evaluation

1. BioSonics, Inc. 1996. Acoustic Evaluation of the Surface Bypass and Collection System at Ice Harbor Dam in 1995. Final Report. Contract No. DACW68-95-C-OO27.

2. BioSonics, Inc. 1995. Executive Summary and Split-Beam Fish Tracking Results From the Report: Acoustic Evaluation of the Surface Bypass and Collection System at Ice Harbor Dam in 1995. Final Report Submitted to CENWW, Walla Walla, WA. BioSonics, Inc.*

3. Johnson, L., C. Noyes, and G.E. Johnson. 1982. Hydroacoustic Evaluation of the Efficiency of the Ice Harbor Dam Ice and Trash Sluiceway for Passing Downstream Migrating Juvenile Salmon and Steelhead, 1982. Volume I. Final Report. BioSonics, Inc., Seattle, Washington.*

4. Johnson, L., C. Noyes, and R. McClure. 1983. Hydroacoustic Evaluation of the Efficiencies of the Ice and Trash Sluiceway and Spillway at Ice Harbor Dam for Passing Downstream Migrating Juvenile Salmon and Steelhead, 1983. Volume I. Draft Report. BioSonics, Inc., Seattle, Washington.*

5. Ransom, B.H. and D.A. Ouellette. 1988. Hydroacoustic Evaluation of Juvenile Fish Passage at Ice Harbor Dam in Spring 1987. Final Report. U.S. Army Corps of Engineers, Walla Walla, Washington.

6. Sullivan, B., L.L. Johnson, and T.H. Schadt. Hydroacoustic Evaluation of Downstream Migrating Salmonids at Ice Harbor Dam in Spring 1986. Document No. 86-1231-012F.

7. Swan, G.A., M.B. Eppard, E.E. Hockersmith, B.P. Sandford, B.L. Iverson, P.A. Ocker, M.A. Kaminski, and R.N. Iwamoto. 1997. Juvenile Radio-Telemetry Study at Ice Harbor Dam, 1995. Annual Report of Research. Draft.*

8. Swan, G.A., M.B. Eppard, E.E. Hockersmith, B.P. Sandford, and R.N. Iwamoto. 1996. Juvenile Radio-Telemetry Study: Ice Harbor Dam, 1995. Summary of Research. Draft.

D.2.3.3 Ice Harbor: Physical Modeling

1. ENSR. 2004. Hydraulic Model Study of Removable Spillway Weir for Juvenile Fish Passage at Ice Harbor Dam. Final Report. Prepared for U.S. Army Corps of Engineers Walla Walla District. ENSR, Redmond, WA. ENSR document no. 06455-030-2511.*

D.3 Lower Columbia River Reference List

D.3.1 McNary Reference List

D.3.1.1 McNary: Physical Modeling

1. ENSR. 2006. Hydraulic Model Study of McNary Dam Surface Fish Bypass. 90% Report. Prepared for U.S. Army Corps of Engineers Walla Walla District. ENSR document no. 09000-387-2620.*

D.3.2 John Day Reference List

D.3.2.1 John Day: Engineering Design

1. CH2M Hill, Montgomery Watson, Northwest Hydraulic Consultants, The Glosten Associates, and Civil Tech. 2001. John Day Surface Bypass Removable Spillway Weir. Design Documentation Report No. 53.*

2. Harza and ENSR. 1996. Surface Bypass Alternatives at Bonneville, The Dalles, and John Day Spillways, Final Report, Vol. 1.*

3. Harza and ENSR. 1996. Surface Bypass Alternatives at Bonneville, The Dalles, and John Day Spillways, Final Report, Vol. 2.

4. Hazara and ENSR. 1995. Surface Bypass Alternative Study at John Day Powerhouse. Final Report Prepared for USACE, Portland District. Volumes 1 and 2. ENSR, Redmond, WA.

5. Montgomery Watson. 1998. John Day Surface Bypass Spillway. Feature Design Memorandum No. 52.*

6. Montgomery Watson, NHC, Glosten Associates, and I. Civil Tech. 2000. John Day Dam Surface Bypass Removable Spillway Weir Physical Model Alternatives Report.

7. U.S. Army Corps of Engineers, Portland District. 19?? John Day Configuration and Operational Plan.

D.3.2.2 John Day: Biological Evaluation

1. Anglea, S., T. Poe, and A. Giorgi. 2001. Synthesis of Radio Telemetry, Hydroacoustic, and Survival Studies of Juvenile Salmon at John Day Dam (1980-2000). Final report.*

2. BioSonics, Inc. 1999. Hydroacoustic Evaluation and Studies at The John Day Dam, 1997. Final Report. BioSonics, Inc., Seattle, Washington.*

3. BioSonics, Inc. 1999. Hydroacoustic Study John Day Dam 1998. Final Report.

4. Dach, R. and J. Ferguson. 1998. Biological Considerations for Development of a Surface Bypass System at John Day Dam.

5. Duran, I. and eight co-authors. 2000. Movement, Distribution and Behavior of Radio-Tagged Juvenile Steelhead and Yearling Chinook Salmon in the Tailrace of John Day Dam, 2000. Annual Report Prepared for U.S. Army Corps of Engineers, Portland District. USGS.

6. Faurot, D., L. Stuerenberg, and C. Sims. 1982. Migrational Characteristics of Juvenile Salmon and Steelhead Trout on the Columbia River System: Vol. II Radio Tracking of Juvenile Salmonids in John Day Reservoir.

7. Giorgi, A.E., D.R. Miller, and B.P. Sandford. 1994. Migratory Characteristics of Juvenile Ocean-Type Chinook Salmon, *Oncorhynchus Tshawytscha*, in John Day Reservoir on The Columbia River. *Fishery Bulletin*. 92(4).

8. Giorgi, A.E. and L.C. Stuehrenberg. 1984. Smolt Passage Behavior and Flow-Net Relationships in the Forebay of John Day Dam. US Department of Energy, Bonneville Power Administration, Portland, Oregon. DOE/BP-347.

9. Hansel, H. and six others. 1999. Estimates of Fish and Spill Passage Efficiency for Radio-Tagged Juvenile Steelhead and Yearling Chinook Salmon at John Day Dam, 1999. Interim Report.

10. Holmberg, G.S., R.S. Shively, H.C. Hansel, T.L. Martinelli, M.B. Sheer, J.M. Hardiman, B.D. Liedtke, L.S. Blythe, and T.P. Poe. 1996. Movement, Distribution, and Behavior of Radio-Tagged Juvenile Chinook Salmon in John Day, The Dalles, and Bonneville Dam Forebays, 1996. Annual report of research. U.S. Geological Survey, Cook, Washington.

11. Johnson, L. and R. Wright. 1987. Hydroacoustic Evaluation of The Spill Program for Fish Passage at John Day Dam in 1987. Final report.

12. Johnston, S., P. Nealson, and J. Horchik. 2000. Hydroacoustic Studies at John Day Dam, Spring/Summer 1999. DRAFT.

13. Magne, R.A., W.T. Nagy, and W.C. Maslen. 1983. Hydroacoustic Monitoring of Downstream Migrant Juvenile Salmonids at John Day Dam 1980-1981. U.S. Army Corps of Engineers, Cascade Locks, Oregon.

14. Magne, R.A., W.T. Nagy, and W.C. Maslen. 1987. Hydroacoustic Monitoring of Downstream Migrant Juvenile Salmonids at John Day Dam in 1983. U.S. Army Corps of Engineers, Cascade Locks, Oregon.

15. McFadden, B. and J. Hedgepeth. 1990. Hydroacoustic Evaluation of Juvenile Salmonid Fish Passage at John Day Dam in Summer 1989. Final report.

16. Moursund, R.A., K.D. Ham, and P.S. Titzler. 2003. Hydroacoustic Evaluation of Downstream Fish Passage at John Day Dam in 2002. Final. PNWD-3236.

17. Sheer, M.B., G.S. Holmberg, R.S. Shively, H.C. Hansel, T.L. Martinelli, T.P. King, C.N. Frost, T.P. Poe, J.C. Snelling, and C.B. Schreck. 1997. Movement and Behavior of Radio-Tagged Juvenile Spring and Fall Chinook Salmon in The Dalles and John Day Dam Forebays, 1995. Final Report. U.S. Army Corps of Engineers, Portland, Oregon.

D.3.2.3 John Day: Physical Modeling

1. Dach, R. 1996. Surface Collection John Day Powerhouse Model (1:40). CENWP-PM-E.

2. ENSR. 1997. Addendum to Final Report: Hydraulic Model Study of Spillway Fish Passage Over/Underflow Baffles for John Day Dam. Prepared for U.S. Army Corps of Engineers Portland District. ENSR document no. 09000-142-800.*

3. ENSR. 1997. Hydraulic Model Study of Spillway Fish Passage Over/Underflow Baffles for John Day Dam. Final Report. Prepared for U.S. Army Corps of Engineers Portland District. ENSR document no. 09000-137-600.*

D.3.3 The Dalles Reference List

D.3.3.1 The Dalles: Engineering Design

1. ENSR. 1997. The Dalles Dam Blocked Trashrack Acoustic Doppler Velocimeter Mapping. Final Report. 9000-134-007.

2. Harza and ENSR. 1996. Surface Bypass Alternatives at Bonneville, The Dalles, and John Day Spillways, Final Report, Vol. 1.*

3. Harza and ENSR. 1996. Surface Bypass Alternatives at Bonneville, The Dalles, and John Day Spillways, Final Report, Vol. 2.

4. HARZA, ENSR, and Fisheries Consultants. 1995. Surface Bypass Alternative Study at The Dalles Powerhouse- Final Report, Volumes 1-2.*

5. U.S. Army Corps of Engineers. 2001. Design Documentation Report No. 32. The Dalles Lock and Dam Sluiceway Outfall With Auxiliary Adult Water. Volumes 1-5.*

6. U.S. Army Corps of Engineers, Portland District. 1996. The Dalles Surface Collection- Powerhouse.

7. U.S. Army Corps of Engineers, Portland District. 1996. The Dalles Surface Collection- Spillway.

D.3.3.2 The Dalles: Biological Evaluation

1. Allen, B. and five co-authors. 2001. Monitoring Tailrace Egress in the Stilling Basin, the Ice-Trash Sluiceway, and the Powerhouse of The Dalles Dam, 2000. Annual report.*

2. Beeman, J., H. Hansel, P. Haner, and J. Hardiman. 2001. Estimates of Fish-, Spill-, and Sluiceway Passage Efficiencies of Radio-Tagged Juvenile Fall Chinook Salmon at The Dalles Dam, 2000. Draft final report.

3. Beeman, J., H. Hansel, P. Haner, and K. Daniel. 2004. Estimates of the Proportions of Radio Tagged Juvenile Salmonids That Passed Via the Spillway, Sluiceway, and Turbines During Tests of Sluiceway Guidance Improvement Devices at The Dalles Dam in 2001. Draft Final Report Prepared by USGS for U.S. Army Corps of Engineers, Portland District.

4. Beeman, J. and seven co-authors. 2002. Estimates of Fish Passage Efficiency of Radio-Tagged Juvenile Salmonids Relative to Operation of J-Design Intake Occlusion Plates at The Dalles Dam, 2002. Anadromous Fish Evaluation Program, (Portland, Oregon).

5. Beeman, J.W., H.C. Hansel, P.V. Haner, S. Juhnke, and K. Daniel. 2002. Estimate the Proportions of Subyearling Chinook Salmon That Pass Via the Spillway, Sluiceway and Turbines Under Each Spill Scenario Tested at The Dalles Dam, 2001: Interim Report of Research. U.S. Geological Survey.

6. BioSonics, Inc. 1996. Hydroacoustic Evaluation and Studies at The Dalles Dam, Spring/Summer 1996. Volume 1 - Fish Passage. Draft Final Report. BioSonics, Inc., Seattle, Washington.

7. BioSonics, Inc. 1997. Hydroacoustic Evaluation and Studies at The Dalles Dam, Spring/Summer 1996. Volume 2 - Smolt Behavior. Final Report. BioSonics, Inc., Seattle, Washington to the Department of the Army, Portland District COE.*

8. BioSonics, Inc. 1999. Hydroacoustic Evaluation and Studies at The Dalles Dam, Spring/Summer 1998.

Final Report.*

9. Cash, K.M., D.M. Faber, T.W. Hatton, E.C. Jones, R.J. Magie, N.M. Swyers, R.K. Burns, M.D. Sholtis, S.A. Zimmerman, J.S. Hughes, T.L. Gilbride, N.S. Adams, and D.W. Rondorf. 2006. Three Dimensional Behavior and Passage of Juvenile Salmonids at The Dalles Dam, 2004. Final Report Submitted to U.S. Army Corps of Engineers, Portland District. Portland, OR. USGS.*

10. Dawley, E.M., L.G. Gilbreath, R.F. Absolon, B.P. Sandford, and J.W. Ferguson. 2000. Relative Survival of Juvenile Salmon Passing Through The Spillway and The Ice and Trash Sluiceway of The Dalles Dam, 1998. Final report. National Marine Fisheries Service, Seattle, Washington.

11. Ebberts, B.D. 1992. Summary Review of Horizontal and Temporal Distribution of Juvenile Salmnoids Across the Powerhouse and Spillway of The Dalles Dam From Hydroacoustic Studies (1982, 1985, 1986, and 1989).

12. Faber, D.M., M.E. Hanks, S.A. Zimmerman, J.R. Skalski, and P.W. Dillingham. 2005. The Distribution and Flux of Fish in the Forebay of The Dalles Dam in 2003. Final Report by PNNL Submitted to the U.S. Army Corps of Engineers, Portland District. PNNL-14628.*

13. Hansel, H. and five co-authors. 2004. Estimates of Fish, Spill and Sluiceway Passage Efficiencies of Radio-Tagged Juvenile Chinook Salmon at The Dalles Dam in 2003. Draft Final Report Prepared by USGS for U.S. Army Corps of Engineers, Portland District.

14. Hansel, H. S.D. Juhnke, P.V. Haner, L. Dingmon, and J.W. Beeman. 2005. Estimates of Fish, Spill and Sluiceway Passage Efficiencies of Radio-Tagged Juvenile Chinook Salmon During Spring and Summer at The Dalles Dam in 2004. Draft Final Report Prepared by USGS, Western Fisheries Research Center, Columbia River Research Laboratory for U.S. Army Corps of Engineers, Portland District.*

15. Hausmann, B., J. Beeman, H. Hansel, S. Juhnke, and P. Haner. 2004. Estimates of the Proportions of Radio Tagged Juvenile Salmonids Relative to Operation of the Sluiceway Guidance Improvement Device at The Dalles Dam in 2002. Final Report Prepared by USGS for U.S. Army Corps of Engineers, Portland District.*

16. Hausmann, B., Beeman, J.W., Hansel, H.C., Juhnke, S., and Haner, P. 2004. Estimates of fish, spill and sluiceway passage efficiences of radio-tagged juvenile salmonids relative to operation of the Sluiceway Guidance Improvement Device in 2002. Report by U.S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory to the U.S. Army COE, Portland District.*

17. Hedgepeth, J.B., G.E. Johnson, A.E. Giorgi, and J.R. Skalski. 2002. Sonar Tracker Evaluation of Fish Movements Relative to J-Occlusions at The Dalles Dam in 2001. Final report submitted to U.S. Army Corps of Engineers, Portland District.*

18. Holmberg, G.S., R.S. Shively, H.C. Hansel, T.L. Martinelli, M.B. Sheer, J.M. Hardiman, B.D. Liedtke, L.S. Blythe, and T.P. Poe. 1996. Movement, Distribution, and Behavior of Radio-Tagged Juvenile Chinook Salmon in John Day, The Dalles, and Bonneville Dam Forebays, 1996. Annual report of research. U.S. Geological Survey, Cook, Washington.

19. Johnson, W.R., L. Johnson, and D.E. Weitkamp. 1987. Hydroacoustic Evaluation of the Spill Program for Fish Passage at The Dalles Dam in 1986. Report by Associate Fisheries Biologists, Inc. and Parametrix, Inc. to Portland District U.S. Army COE.*

20. Johnson, G., M. Hanks, J. Hedgepeth, B. McFadden, R. Moursund, R. Mueller, and J. Skalski. 2003. Hydroacoustic Evaluation of Turbine Intake J-Occlusions at The Dalles Dam in 2002. Final Report Submitted to the U. S. Army Corps of Engineers, Portland District, Portland, OR. PNWD-3226.*

21. Johnson, G. and seven co-authors. 2006. Hydroacoustic Evaluation of Juvenile Salmonid Passage at The Dalles Dam Sluiceway, 2005. Final Report Prepared for U.S. Army Corps of Engineers, Portland District. PNNL-15540.*

22. Johnson, G.E., J.B. Hedgepeth, J.R. Skalski, and A.E. Giorgi. 2004. A Markov Chain Analysis of Fish Movement to Determine Entrainment Zones. Fisheries Research. pp. 349-358.*

23. Johnson, G.E., J.B. Hedgepeth, A.E. Giorgi, and J.R. Skalski. 2001. Evaluation of Smolt Movements Using an Active Fish Tracking Sonar at The Sluiceway Surface Bypass, The Dalles Dam, 2000. Final report submitted to the U.S. Army Corps of Engineers, Portland District. BioAnalysts, Inc., Battle Ground, WA.*

24. Johnson, G.E., M.E. Hanks, F. Khan, J.B. Hedgepeth, R.P. Mueller, C.L. Rakowski, M.C. Richmond, S.L. Sargeant, J.A. Serkowski, and J.R. Skalski. 2005. Hydroacoustic Evaluation of Juvenile Salmonid Passage at The Dalles Dam in 2004. Final report submitted to the Corps of Engineers, Portland District by PNNL, Richland, WA. PNNL-15180.*

25. Johnson, G.E. and six co-authors. 2003. Hydroacoustic Evaluation of Turbine Intake J-Occlusions at The Dalles Dam in 2002. Final report submitted to the U. S. Army Corps of Engineers, Portland District. Battelle Pacific Northwest Division, Richland, WA. PNWD-3226.

26. Johnson, R.L., D.S. Daly, T. Redgate, A. Hoffman, and T.J. Carlson. 1995. A Model to Describe Smolt Behavior During Approach to Surface Collector Prototypes, The Dalles Dam, Spring 1995. Draft. Pacific Northwest National Laboratory, Richland, Washington.

27. McFadden, B.D. 1990. Hydroacoustic Evaluation of Juvenile Salmonid Fish Passage at The Dalles Dam in Summer 1989. Final report by BioSonics, Inc. to the U.S. Army Corps of Engineers, Portland District.*

28. Moursund, R.A., K.D. Ham, P.S. Tizler, R.P. Mueller, G.E. Johnson, J.B. Hedgepeth, and J.R. Skalski. 2002. Hydroacoustic Evaluation of Fish Passage at The Dalles Dam in 2001. Final report submitted to U. S. Army Corps of Engineers, Portland District.*

29. Nagy, W.T. and M.K. Shutters. 1995. Hydroacoustic Evaluation of Surface Collector Prototypes at The Dalles Dam, 1995. Draft. U.S. Army Corps of Engineers, Cascade Locks, Oregon.*

30. Nichols, D.W. 1980. Development of Criteria for Operating the Trash Sluiceway at The Dalles Dam As a Bypass System for Juvenile Salmonids, 1979. Report Prepared for the U.S. Army Corps of Engineers, Portland District. Oregon Department of Fish and Wildlife.*

31. Nichols, D.W. 1979. Passage Efficiency and Mortality Studies of Downstream Migrant Salmonids Using The Dalles Ice Trash Sluiceway During 1978. Oregon Department of Fish and Wildlife.*

32. Nichols, D.W., F.R. Young, and C.O. Junge. 1978. Evaluation of The Dalles Dam Ice-Trash Sluiceway As a Downstream Migrant Bypass System During 1977. Report Submitted to CENWP, Portland, OR. ODFW.*

33. Nichols, D.W. and B.H. Ransom. 1981. Development of The Dalles Dam Trash Sluiceway As a

Downstream Migrant Bypass System, 1980. Oregon Department of Fish and Wildlife, Portland, Oregon.*

34. Nichols, D.W. and B.H. Ransom. 1982. Development of The Dalles Dam Trash Sluiceway As a Downstream Migrant Bypass System, 1981. Draft. Oregon Department of Fish and Wildlife, Portland, Oregon.*

35. Oregon Department of Fish and Wildlife. 1978. Evaluation of The Dalles Dam Ice-Trash Sluiceway As a Downstream Migrant Bypass System During 1977. Oregon Department of Fish and Wildlife, Clackamas, Oregon.

36. Ploskey, G., B. Nagy, L. Lawrence, M. Hanks, C. Schilt, P. Johnson, G. Johnson, D. Patterson, and J. Skalski. 2001. Hydroacoustic Evaluation of Juvenile Salmon Passage at The Dalles Dam: 1999. Final report. ERDC/EL TR-01-11.

37. Ploskey, G., T. Poe, A. Giorgi, and G. Johnson. 2001. Synthesis of Radio Telemetry, Hydroacoustic, and Survival Studies of Juvenile Salmon at The Dalles Dam (1982-2000). Final Report.*

38. Rakowski, C.L., Richmond, M.C., Serkowski, J.A., Johnson, G.E. 2006. Forebay computational fluid dynamics modeling for The Dalles Dam to support behavior guidance system siting studies. Report by PNNL to the U.S. Army COE.*

39. Sheer, M.B., G.S. Holmberg, R.S. Shively, H.C. Hansel, T.L. Martinelli, T.P. King, C.N. Frost, T.P. Poe, J.C. Snelling, and C.B. Schreck. 1997. Movement and Behavior of Radio-Tagged Juvenile Spring and Fall Chinook Salmon in The Dalles and John Day Dam Forebays, 1995. Final Report. U.S. Army Corps of Engineers, Portland, Oregon.

40. Steig, T.W. and W.R. Johnson. 1986. Hydroacoustic Assessment of Downstream Migrating Salmonids at The Dalles Dam in Spring and Summer 1985. Final Report. U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon. DOE/BP-23174-2.

D.3.3.3 The Dalles: Physical Modeling

1. CEWES-HS-S. 1996. Memorandum, 17 September 1996, Summary on Dalles 6-bay spillway model – 1:40 scale.

2. ENSR. 1997. Hydraulic Model Study of Spillway Fish Passage Over/Underflow Bulkhead for the Dalles Dam. Prepared for USACE, Portland District. ENSR, Redmond, WA. ENSR document number 9000-089-300.*

3. U.S. Army Corps of Engineers, Portland District. 1995. The Dalles 1:25 Turbine Intake Model- Surface Collection, 1995.

4. U.S. Army Corps of Engineers, Portland District. 1996. The Dalles Dam Surface Collection: General Model.

D.3.3.4 The Dalles: Multidisciplinary

1. INCA, NHC, and Hamilton Engineering. 1999. Combined System Study The Dalles Dam. Final Report.

2. U.S. Army Corps of Engineers. 2005. The Dalles Juvenile Behavior Guidance System (BGS) Feasibility Report. U.S. Army Corp of Engineers, Walla Walla District, Washington.*

3. U.S. Army Corps of Engineers, Portland District. 1997. The Dalles Lock and Dam, Ice and Trash Sluiceway Outfall Locations Study. Letter report.

4. U.S. Army Corps of Engineers, Portland District. 2006. Design Documentation Report No. 34. The Dalles Lock and Dam Juvenile Behavioral Guidance System (BGS). 100% Review February 2006.*

D.3.4 Bonneville Reference List

D.3.4.1 Bonneville: Engineering Design

1. BioAnalysts, ENSR, and INCA. 2001. Bonneville Second Powerhouse Corner Collector Site Selection Study. Final Submittal.*

2. Davidson, R. 2000. First Powerhouse, Bonneville Dam, Columbia River, Oregon Report 2, Tracking Velocities. ERDC/CHL.

3. ENSR, Harza, INCA, and Cornforth Consultants. 1989. Bonneville First Powerhouse Juvenile Fish Surface Bypass High Flow Dewatering Facility and Outfall Alternatives Study. Final report submitted to Portland District, U.S. Army Corps of Engineers.*

4. ENSR and INCA. 2000. Hydraulic Calculations Supporting Bonneville Surface Collection High Flow Outfall Guidelines Research, Contract No. DACW57-97-D-0003, INCA Engineers, Task Order No. 20, Modification Case No. 01.*

5. Harza and ENSR. 1996. Bonneville First Powerhouse 1997 Prototype Surface Collector System. Letter Report.*

6. Harza and ENSR. 1996. Surface Bypass Alternative Study at Bonneville First Powerhouse, Volume 1. Final Report Prepared for U.S. Army Corps of Engineers, Portland District.*

7. Harza and ENSR. 1996. Surface Bypass Alternative Study at Bonneville First Powerhouse: Volume 2. Final Report prepared for the U.S. Army Corps of Engineers, Portland District.*

8. Harza and ENSR. 1996. Surface Bypass Alternative Study at Bonneville Second Powerhouse. Final Report. Volume 1. U.S. Army Corps of Engineers, Portland, Oregon. DACW57-95-D-0003.

9. Harza and ENSR. 1996. Surface Bypass Alternative Study at Bonneville Second Powerhouse. Final Report. Volume 2. U.S. Army Corps of Engineers, Portland, Oregon.*

10. Harza and ENSR. 1996. Surface Bypass Alternatives at Bonneville, The Dalles, and John Day Spillways, Final Report, Vol. 1.*

11. Harza and ENSR. 1996. Surface Bypass Alternatives at Bonneville, The Dalles, and John Day Spillways, Final Report, Vol. 2.*

12. Harza and ENSR. 1995. Surface Bypass at the Bonneville Second Powerhouse- 95% Submittal-Alternatives Refinement and Prototype Development.*

13. U.S. Army Corps of Engineers, Portland District. 2002. Bonneville Second Powerhouse Corner Collector Surface Flow Bypass System Design Documentation Report No. 47. Bonneville Lock and Dam, Columbia River Basin, Washington – Oregon. Mar 15.

14. U.S. Army Corps of Engineers. 2001. 90 Percent Design Documentation Report. Bonneville Second Powerhouse High Flow Outfall Bypass System. USACE Portland District, Portland, OR.*

15. U.S. Army Corps of Engineers, Portland District. 1999. Bonneville Second Powerhouse High Flow Outfall Siting and Exit Structure- WES Trips.

16. U.S. Army Corps of Engineers, Portland District. 1999. Bonneville Surface Collection: High Flow Outfalls- 1999. CENWP-EC-HD.

17. U.S. Army Corps of Engineers, Portland District. 1998. Bonneville Surface Collection Second Powerhouse Ice & Trash Chute.

D.3.4.2 Bonneville: Biological Evaluation

1. Abernethy, C.S., D.A. Neitzel, and W.V. Mavros. 1996. Movement and Injury rates for Three Life Stages of Spring Chinook Salmon Oncorhynchus tshawytscha: A Comparison of Submerged Orifices and an Overflow Weir for Fish Bypass in a Modular Rotary Drum Fish Screen. Annual Report 1995. Submitted to the Bonneville Power Administration, Portland, Oregon, March 1996.

2. BioSonics Inc. 1998. Hydroacoustic Evaluation and Studies at Bonneville Dam, Spring/Summer 1997 Volume 1 and 2. Contract Report to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon.*

3. Dawley, E. M., R. D. Ledgerwood, L. G. Gilbreath, B. P. Sandford, P. J. Bentley, M. H. Schiewe, and S. J. Grabowski. 1992. Survival of Juvenile Salmon Passing through Bonneville Dam and Tailrace. in. Passage and Survival of Juvenile Chinook Salmon Migrating from the Snake River Basin. Proceedings of a Technical Workshop, Feb 26-28, 1992 University of Idaho, pages 145-156.

4. Evans, S., L. Wright, R. Reagan, N. Adams, and D. Rondorf. 2005. Passage Behavior of Radio-Tagged Subyearling Chinook Salmon at Bonneville Dam, 2004. Draft Annual Report Submitted to CENWP, Portland, OR. USGS.*

5. Evans, S.D., C.D. Smith, N.S. Adams, and D.W. Rondorf. 2001. Passage Behavior of Radio-Tagged Yearling Chinook Salmon at Bonneville Dam, 2001. Annual Report, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

6. Evans, S.D., J.M. Plumb, A.C. Braatz, K.S. Gates, N S. Adams, and D.W. Rondorf. 2001. Passage Behavior of Radio-Tagged Yearling Chinook Salmon and Steelhead at Bonneville Dam Associated With the Surface Bypass Program, 2000. Annual Report, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

7. Evans, S.D., N.S. Adams, and D.W. Rondorf. 2001. Passage Behavior of Radio-Tagged Subyearling Chinook Salmon at Bonneville Dam Associated With the Surface Bypass Program, 2000. Annual Report, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

8. Evans, S.D., C.D. Smith, N.S. Adams, and D.W. Rondorf. 2001. Passage Behavior of Radio-Tagged Subyearling Chinook Salmon at Bonneville Dam, 2001. Annual Report, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

9. Evans, S.D., L.S. Wright, C.D. Smith, R.E. Wardell, N.S. Adams, and D.W. Rondorf. 2003. Passage Behavior of Radio-Tagged Yearling Chinook Salmon and Steelhead at Bonneville Dam, 2002.

10. Evans, S.D., L.S. Wright, R.E. Wardell, N.S. Adams, and D.W. Rondorf. 2003. Passage Behavior of

Radio-Tagged Subyearling Chinook Salmon at Bonneville Dam, 2002. Annual Report, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

11. Faber, D.M., M.A. Weiland, R.A. Moursund, T.J. Carlson, N. Adams, and D. Rhondorf. 2001. Evaluation of the Fish Passage Effectiveness of the Bonneville I Prototype Surface Collector Using Three-Dimensional Ultrasonic Fish Tracking. Contract DE-AC06-76RLO1830 Related Services, Pacific Northwest National Laboratory, Richland, Washington.*

12. Gauley, J.E., R.E. Anas, and L.C. Schlotterbeck. 1958. Downstream Movement of Salmonids at Bonneville Dam. U. S. Fish and Wildlife Service, Special Scientific Report #236, Washington, DC.

13. Gilbreath, L. G., E. M. Dawley, R.D. Ledgerwood, P.J. Bentley, and S.J. Grabowski. 1993. Relative Survival of Subyearling Chinook Salmon that Have Passed Bonneville Dam via the Spillway or Second Powerhouse Turbines or Bypass System: Adult Recoveries through 1991. Final report submitted to Portland District, U.S. Army Corps of Engineers.

14. Hansel, H.C., R.S. Shively, J.E. Hensleigh, B.D. Liedtke, T. Hatton, R.E. Wardell, R.H. Wertheimer, and T.P. Poe. 1999. Movement, Distribution, and Behavior of Radio-Tagged Subyealing Chinook Salmon in the Forebay of Bonneville Dam, 1998. Annual report.

15. Hensleigh, J.E., R. S. Shively, H. C. Hansel, J. M. Hardiman, G. S. Holmberg, B. D. Liedtke, T. L. Martinelli, R. E. Wardell, R. H. Wertheimer, and T. P. Poe. 1999. Movement, Distribution and Behavior of Radio-Tagged Juvenile Chinook Salmon and Steelhead in John Day, The Dalles and Bonneville Dam Forebays, 1997. Annual Report of Research.

16. Hensleigh, J.E., R.S. Shively, H.C. Hansel, J.M. Hardiman, G.S. Holmberg, B.D. Liedtke, T.L. Martinelli, R.E. Wardell, R.H. Wertheimer, and T.P. Poe. 1999. Movement, Distribution and Behavior of Radio-Tagged Juvenile Chinook Salmon and Steelhead in John Day, The Dalles and Bonneville Dam Forebays, 1997. Annual Report of Research.

17. Holmberg, G.S., R. E. Wardell, M. G. Mesa, N. S. Adams, and D. W. Rondorf. 2001. Evaluation of the Bonneville Dam Second Powerhouse Juvenile Bypass System, 2000. Annual Report, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

18. Holmberg, G.S., R. E. Wardell, M. G. Mesa, N. S. Adams, and D. W. Rondorf. 2001. Evaluation of the Bonneville Dam Second Powerhouse New Juvenile Bypass System, 1999. Annual Report, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

19. Holmberg, G.S., R.S. Shively, H.C. Hansel, T.L. Martinelli, M.B. Sheer, J.M. Hardiman, B.D. Liedtke, L.S. Blythe, and T.P. Poe. 1996. Movement, Distribution, and Behavior of Radio-Tagged Juvenile Chinook Salmon in John Day, The Dalles, and Bonneville Dam Forebays, 1996. Annual report of research. U.S. Geological Survey, Cook, Washington.

20. Holmberg, G.S., R.E. Wardell, M.G. Mesa, N.S. Adams, and D.W. Rondorf. 2001. Evaluation of the Bonneville Dam Second Powerhouse Juvenile Bypass System, 2000. Annual Report, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

21. Johnson, G. and T. Carlson. 2001. Monitoring and Evaluation of the Prototype Surface Collector at Bonneville First Powerhouse in 2000: Synthesis of Results. Final report.*

22. Johnson, G.E. and A.E. Giorgi. 1999. Development of Surface Flow Bypasses at Bonneville Dam: A Synthesis of Data From 1995 to 1998 and a Draft M&E Plan for 2000. BioAnalysts, Inc., Vancouver, WA.*

23. Johnson, R., M.A. Simmons, C.S. Simmons, K.D. Hand, and J. Thomas. 2000. Evaluation of Fish Behavior In Front of the Prototype Surface Collector at Bonneville Dam, 1999. Final Report.

24. Johnson, R.L. 1970. Tests of Fingerling Passage at Bonneville Dam. Summary. Report No. 18. U.S. Army Corps of Engineers, North Pacific Division, Fisheries-Engineering Research Program, August 1970.

25. Johnson, R.L., R.A. Moursund, and M.A. Simmons. 1999. Fish Behavior in Front of the Prototype Surface Collector at Bonneville Dam in 1998: Final Report.

26. Johnson, R.L., et al. 2001. Hydroacoustic Evaluation of Fish Behavior at Bonneville Dam First Powerhouse: 2000 Prototype Surface Flow Bypass: Final Report. Battelle.

27. Knutsen, C.J. and R.H. Reeves. 1996. Distribution and Behavior of Northern Squawfish in Bonneville Dam Forebay, 1996. Draft.

28. Magne, R.A. 1987. Bonneville II Hydroacoustic Monitoring Memorandum for the Record #1, 27 May 1987.

29. Magne, R.A. 1987. Hydroacoustic Monitoring at the Bonneville Dam Project in 1988. Proposal Plus 1987 Data. Draft. U.S. Army Corps of Engineers, Cascade Locks, Oregon.

30. Magne, R.A. 1987. Hydroacoustic Monitoring of Downstream Migrant Juvenile Salmonids at Bonneville Dam, 1987. U.S. Army Corp of Engineers, Portland District, Operations Division, Fisheries Field Unit, Bonneville Lock and Dam, Cascade Locks, Oregon.

31. Magne, R.A. 1984. Hydroacoustic Survey of the Bonneville Second Powerhouse Forebay to Determine the Spatial Distribution of Outmigrant Juvenile Salmonids. U.S. Army Corps of Engineers, Portland District, NPPOP-RM-FFU, Fisheries Office, Bonneville Lock and Dam, Cascade Locks, Oregon.

32. Magne, R.A., D. J. Rawding, and W.T. Nagy. 1986. Hydroacoustic Monitoring at the Bonneville Dam Second Powerhouse During 1986 Fish Guiding Efficiency Tests. Fishery Field Unit, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

33. Magne, R.A., R. Stansell, and W.T. Nagy. 1989. A Summary of Hydroacoustic Monitoring at the Bonneville Dam Second Powerhouse in 1988. U.S. Army Corps of Engineers, Cascade Locks, Oregon.

34. Magne, R.A., D.J. Rawding, and W.T. Nagy. 1986. Hydroacoustic Monitoring at the Bonneville Dam Second Powerhouse During 1986 Fish Guiding Efficiency Tests. Fishery Field Unit, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

35. Michimoto, R.T. 1971. Bonneville and The Dalles Dams Ice-Trash Sluiceway Studies, 1971. U. S. Army Corps of Engineers, North Pacific Division, Fisheries-Engineering Research Program, Portland, Oregon, Report #20.*

36. Michimoto, R.T. and L. Korn. 1969. A Study to Determine the Value of Using the Ice-Trash Sluiceway for Passing Downstream-Migrant Salmonids at Bonneville Dam. Final report.*

37. Monk, B., M. Gessel, and J. Ferguson. 1999. An Evaluation of the Existing Biological Database at Bonneville Second Powerhouse for Improving FGE. Final report by NMFS, Seattle, WA. 62 pp. April 1999.

38. Nagy, W.T. and R.A. Magne. 1986. Hydroacoustic Study of Juvenile Fish Passage at the Bonneville Second Powerhouse in 1985. Final report.

39. Normandeau Associates Inc., J. Skalski, and Mid Columbia Consulting Inc. 2001. Passage Survival Investigation of Juvenile Chinook Salmon Through Bonneville Powerhouse II Bypass Sluice at Two Tailwater Conditions, Columbia River, Washington. Prepared for U.S. Army Corps of Engineers, Portland District, Portland, Oregon. Final report.

40. Ploskey, G., P.N. Johnson, W.T. Nagy, C.R. Schilt, L.R. Lawrence, D.S. Patterson, J. Skalski. 1999. Hydroacoustic Evaluation of the Bonneville PH1 Prototype Surface Collection in 1999. Draft technical report.*

41. Ploskey, G., W. Nagy, L. Lawrence, D. Patterson, C. Schilt, P. Johnson, and J. Skalski. 2001. Hydroacoustic Evaluation of Juvenile Salmonid Passage Through Experimental Routes at Bonneville Dam in 1998. Final Report. ERDC/EL TR-01-2.*

42. Ploskey, G., M.A. Weiland, C.R. Schilt, P.N. Johnson, M.E. Hanks, D.S. Patterson, J.R. Skalski, and J. Hedgepath. 2005. Hydroacoustic Evaluation of Fish Passage at Bonneville Dam in 2004. Final Report Submitted to CENWP, Portland, Oregon. PNNL.*

43. Ploskey, G.R., C.R. Schilt, J. Kim, C.W. Escher, and J.R. Skalski. 2003. Hydroacoustic Evaluation of Fish Passage Through Bonneville Dam in 2002. Final report submitted by Battelle to the U.S. Army Corps of Engineers, Portland District. PNNL-14356.*

44. Ploskey, G.R., C. R. Schilt, M. E. Hanks, J. R. Skalski, W. T. Nagy, P. N. Johnson, D. S. Patterson, J. Kim, and L. R. Lawrence. 2002. Hydroacoustic Evaluation of Fish Passage Through Bonneville Dam in 2000. ERDC/EL TR-02-8, U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

45. Ploskey, G.R., C. R. Schilt, M. E. Hanks, J. R. Skalski, W. T. Nagy, P. N. Johnson, D. S. Patterson, J. Kim, and L. R. Lawrence. 2002. Hydroacoustic Evaluation of a Prototype Surface Collector and in-Turbine Screens at Bonneville Dam Powerhouse 1 in 2000. ERDC/EL TR-02-15, U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.

46. Ploskey, G.R., C.R. Schilt, M.E. Hanks, P.N. Johnson, J. Kim, J.S. Skalski, D.S. Patterson, W.T. Nagy, and L.R. Lawrence. 2002. Hydroacoustic Evaluation of Fish-Passage Efficiency at Bonneville Dam in 2001. Final Report. PNNL. PNNL-14047.*

47. Ploskey, G.R., P.N. Johnson, W.T. Nagy, C.R. Schilt, L.R. Lawrence, D.S. Patterson, and J.R. Skalski. 2001. Hydroacoustic Evaluation of the Bonneville Dam Prototype Surface Collector in 1999. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi. ERDC/EL TR-01-1.

48. Ploskey, G.R., L.R. Lawrence, P.N. Johnson, W.T. Nagy, and M.G. Burczynski. 1998. Hydroacoustic Evaluations of Juvenile Salmonid Passage at Bonneville Dam Including Surface-Collection Simulations. Technical Report EL-98-4. Final report for 1996. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.*

49. Ploskey, G.R., C.R. Schilt, M.E. Hanks, J.R. Skalski, W.T Nagy, P.N. Johnson, D.S. Patterson, J. Kim, L.R. Lawrence. 2002. Hydroacoustic Evaluation of a Prototype Surface Collector and In-Turbine Screens at Bonneville Dam First Powerhouse in 2000. Report by PNNL, MEVATEC Corp., DynTel Corp., WES, USAE District, and the University of Washington to U.S. Army Engineer District, Portland.*

50. Ploskey, G. R. et al. 2001. Hydroacoustic Evaluations of Juvenile Salmonid Passage Through Experimental Routes at Bonneville Dam in 1998. Technical report submitted to Portland District, U.S. Army Corps of Engineers. January 2001.

51. Plumb, J.M., M.S. Novick, B.D. Liedtke, and N.S. Adams. 2001. Passage Behavior of Radio-Tagged Yearling Chinook Salmon and Steelhead at Bonneville Dam Associated With the Surface Bypass Program, 1999. Annual Report, U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

52. Plumb, J.M., M.S. Novick, B.D. Liedtke, and N.S. Adams. 2001. Passage Behavior of Radio-Tagged Yearling Chinook Salmon and Steelhead at Bonneville Dam Associated With the Surface Bypass Program, 1999. Annual Report. U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

53. Plumb, J.M., M.S. Novick, B.D. Liedtke, and N.S. Adams. 2001. Movement, Distribution, and Behavior of Radio-Tagged Yearling Spring Chinook Salmon and Juvenile Hatchery Steelhead in the Forebay of Bonneville Dam, 1999. Report of U.S. Geological Survey, Biological Resources Division (Contract W66QKZ90432766) to U.S. Army Corps of Engineers, Portland, Oregon.

54. Reagan, G., N. Adams, and D. Rondorf. 2005. Passage Behavior of Radio-Tagged Yearling Chinook Salmon at Bonneville Dam, 2004. Draft Annual Report Submitted to CENWP, Portland, OR. USGS.*

55. Snelling, J.C. and S.A. Mattson. 1996. Movement and Behavior of Juvenile Salmonids at Three Lower Columbia River Dams. Year-End Report for 1996.

56. Snelling, J.C. and S.A. Mattson. 1996. Movement and Behavior of Juvenile Salmonids at Three Lower Columbia River Dams. Year-end report for 1996.

57. Stansell, R.J., R.A. Magne, W.T. Nagy, and L.M. Beck. 1990. Hydroacoustic Monitoring of Downstream Migrant Juvenile Salmonids at Bonneville Dam, 1989. U.S. Army Corps of Engineers, Cascade Locks, Oregon.

58. Thorne, R.E. and E. S. Kuehl. 1989. Evaluation of Hydroacoustics Techniques for Assessment of Juvenile Fish Passage at Bonneville Powerhouse I. Final Report by =BioSonics, Inc., Seattle, Washington for the U.S. Army Engineer, Portland District, Portland, Oregon.

59. Thorne, R.E. and G. E. Johnson. 1993. A Review of Hydroacoustic Studies for Estimation of Salmonid Downriver Migration Past Hydroelectric Facilities on the Columbia and Snake Rivers in the 1980s. *Reviews in Fisheries Science*. 1 (1).

60. Thorne, R.E. and E.S. Kuehl. 1989. Evaluation of Hydroacoustics Techniques for Assessment of Juvenile Fish Passage at Bonneville Powerhouse I. Final Report Prepared for the U.S. Army Engineer, Portland District, Portland, Oregon. BioSonics, Inc., Seattle, Washington.

61. Uremovich, B.L., S.P. Cramer, C.F. Willis, and C.O. Junge. 1982. Passage of Juvenile Salmonids Through the Ice-Trash Sluiceway and Squawfish Predation at Bonneville Dam, 1980. Annual Progress Report. Oregon Department of Fish and Wildlife.*

62. Willis, C.F. 1982. Development and Evaluation of the Bonneville Dam First Powerhouse Sluiceway As a Juvenile Salmonid Bypass System. Final Summary Report Submitted to the U. S. Army Corps of Engineers and the National Marine Fisheries Service. Oregon Department of Fish and Wildlife.*

63. Willis, C.F. 1981. Part 1 - Development and Evaluation of the Bonneville Dam First Powerhouse Sluiceway As a Juvenile Salmonid Bypass System and Part 2 - Evaluation of Juvenile Salmonid Losses to Predation by Northern Squawfish in the Bonneville Dam First Powerhouse Forebay. Final summary report.

64. Willis, C.F. and B.L. Uremovich. 1982. Evaluation of The Ice and Trash Sluiceway at Bonneville Dam As A Bypass System for Juvenile Salmonids, 1981. Final report submitted to Portland District, U.S. Army Corps of Engineers.*

D.3.4.3 Bonneville: Numerical Modeling

1. Rakowski, C.L., J.A. Serkowski, M.C. Richmond, and K.P. Recknagle. 2001. Development and Application of a 3D CFD Model for the Bonneville Project Powerhouse 1 and Powerhouse 2, Final Report. September 6, 2001.

D.3.4.4 Bonneville: Physical Modeling

1. ENSR and INCA. 2001. Bonneville Second Powerhouse Corner Collector Outfall, Model Study of Bottom Impact and Ambient Flow Sensitivity. Final Report. Prepared for U.S. Army Corps of Engineers Portland District. ENSR, Redmond, WA. ENSR document no. 3697-002-430.*

2. ENSR and INCA Engineers. 2002. Bonneville Second Powerhouse Corner Collector Outfall Final Design Documentation. Final Report. Prepared for U.S. Army Corps of Engineers Portland District. ENSR, Redmond, WA. ENSR document no. 03697-013-804.*

3. ENSR and INCA Engineers. 2002. Bonneville Second Powerhouse Corner Collector Outfall. Final Report. Prepared for U.S. Army Corps of Engineers Portland District. ENSR, Redmond, WA. ENSR document no. 03697-013-430.*

4. ENSR and INCA Engineers. 2002. Bonneville Second Powerhouse Corner Collector Outfall Type and Site Selection Support Studies. Final Report. Prepared for U.S. Army Corps of Engineers Portland District. ENSR, Redmond, WA. ENSR document no. 03697-013-400.*

5. U.S. Army Corps of Engineers, Portland District. 1998. Bonneville Surface Collection: First Powerhouse PSC- 1998 & 1999- Forebay Model Data (1:40).

6. U.S. Army Corps of Engineers, Portland District. 1997. Bonneville Surface Collection: First Powerhouse PSC- Development- Forebay Model Data (1:40).

7. U.S. Army Corps of Engineers, Portland District. 1997. Bonneville Surface Collection General Model Data (1:100). Portland, Oregon.

8. U.S. Army Corps of Engineers, Portland District. 1997. Bonneville Surface Collection: High Flow Outfall Location Physical Hydraulic Modeling.

9. U.S. Army Corps of Engineers, Portland District. 1999. Bonneville Surface Collection Second Powerhouse Corner Collector Forebay Model Data (1:40). Portland, Oregon.

10. U.S. Army Corps of Engineers, Portland District. 1995. Surface Collection Bonneville General Model 1:100. Portland, Oregon.

D.3.4.5 Bonneville: Multidisciplinary

1. BioAnalysts, ENSR, and INCA. 2000. Bonneville First Powerhouse High Flow Outfall Site Selection Study. Final submittal.*

2. CH2M Hill, Montgomery Watson, BioAnalysts, Inc., and Pacific Northwest Laboratory. 1998. Bonneville Dam Second Powerhouse Physical Guidance Device. Letter Report. U.S. Army Corps of Engineers, Portland, Oregon.*

3. Harza Engineering Co., M.B. HDR, R2 Resource Consultants, BioAnalysts, and ENSR. 2001. Bonneville First Powerhouse Deep Slot Surface Collector Prototype Alternatives Study. Final submittal.*

4. INCA Engineers, BioAnalysts, Chinook Engineering, ENSR, and R2 Resource Consultants. 1999. Bonneville 2ND Powerhouse Fish Guidance Efficiency Improvement Study. Final Report. Prepared for U.S. Army Corps of Engineers Portland District.*

5. INCA Engineers, FishPro, Northwest Hydraulic Consultants, R.W. Beck, AGRA Earth and Environmental, BioAnalysts, and Battelle Pacific Northwest Laboratories. 1997. Bonneville Second Powerhouse Prototype Corner Collector. Final Report. Prepared for U.S. Army Corps of Engineers Portland District.*

6. U.S. Army Corps of Engineers. 1992. Bonneville Second Powerhouse Fish Guidance Efficiency Improvements. Design Memorandum 42. USACE, Portland District, Portland, OR.*

7. U.S. Army Corps of Engineers, Portland District. 2002. Bonneville Decision Document Juvenile Fish Passage Recommendation.*

D.4 Other Pacific Northwest Rivers

D.4.1 Mayfield Reference List

D.4.1.1 Mayfield: Engineering Design

1. Richey, E.P. 1957. A Model Study of Some Fish Facilities for the Proposed Mayfield Dam. Part I. The Skimmer. University of Washington, The Trend in Engineering, Washington.

D.4.1.2 Mayfield: Biological Evaluation

1. Normandeau Assoc. and J.R. Skalski. 2003. Passage Survival of Juvenile Salmonids Through Two Francis Turbines at Mayfield Dam, Cowlitz River, Washington. Normandeau and Associates, Inc. prepared for Tacoma Power. October 2003.

2. Smith, J.R., J.R. Pugh, and G.E. Monan. 1968. Horizontal and Vertical Distribution of Juvenile Salmonids in Upper Mayfield Reservoir, Washington. United States Fish and Wildlife Service, Washington, D.C. Special Scientific Report - Fisheries No. 566.*

3. Thompson, J.S. and G.J. Paulik. 1967. An Evaluation of Louvers and Bypass Facilities for Guiding Seaward Migrant Salmonids Past Mayfield Dam in Western Washington. Prepared for the City of Tacoma, Tacoma, WA. State of Washington, Department of Fisheries, Research Division and the University of Washington.*

4. Thompson, J.S. and L. Rothfus. 1969. Biological Observations of Salmonids Passing Mayfield Dam. Washington Department of Fisheries, Olympia, WA.

D.4.1.3 Mayfield: Multidisciplinary

1. Zapel, E., T. Molls, S.V. Johnson, P.A. Nealson, and M.A. Timko. 2001. Evaluation of Juvenile Coho Salmon Behavior and Passage Through the Intake Louvers at Mayfield Dam in 2001 Using Acoustic Tags. Correlation of Acoustic Tag Tracking Data With Velocity Vector Field Generated With a 3-Dimensional Computational Fluid Dynamic (CFD) Numerical Computer Model. Velocity Field Verification With 3-Dimensional Point Velocities Measured in the Existing Intake With ADV Probe.*

2. Zapel, E., T. Molls, S. Johnston, P. Nealson and M. Timko. 2002. Cowlitz River Project Mayfield Dam Fish Guidance Louver Evaluations, Final Report.

D.4.2 Cowlitz Falls Reference List

D.4.2.1 Cowlitz Falls: Engineering Design

1. ENSR. 2006. Post-Construction Hydraulic Verification of Cowlitz Falls Hydroelectric Project Prototype Fish Screen. Prepared for MWH and Tacoma Power. Final Report. 03830-014-1180. ENSR, Redmond, WA.*

2. MWH and ENSR. 2005. Prototype Fish Screen At Cowlitz Hydroelectric Project Design Basis Report.*

D.4.2.2 Cowlitz Falls: Biological Evaluation

1. Adams, N.S., J.M. Plumb, K.M. Cash, S.D. Evans, D.M. Faber, M.S. Novick, R.W. Perry, and D.W. Rondorf. 1999. Behavior of Juvenile Salmonids at Cowlitz Falls Dam, Washington--Final Report for 1998. Lewis County PUD, Randle, WA.

2. Darland, T.J., D.H. Feil, B.J. Hausman, C.D. Smith, and D.W. Rondorf. 2001. Evaluation of Directed Flow to Improve Fish Guidance for the Surface Collection Program, Cowlitz Falls Dam. U.S. Geological Survey.

3. Darland, T.J., S.D. Evans, G. L. Rutz, B.J. Hausman, D.W. Rondorf, N.S. Adams, C.F. Morrill, and J.D. Serl. 2001. Test of Concept to Improve Fish Guidance Using Induced Water Currents at Cowlitz Falls Dam, Washington. Bonneville Power Administration, Portland, OR.

4. Harza. 1999. 90% Draft Fish Passage Study. Cowlitz River Hydroelectric Project FERC No. 2016. HARZA, Tacoma, WA.

D.4.2.3 Cowlitz Falls: Physical Modeling

1. Hazara Northwest, Inc. and ENSR. 1993. Hydraulic Model Studies for Fish Collection Facilities. Bonneville Power Administration and Public Utility District No. 1 of Lewis County Cowlitz Falls Project. Final Report. ENSR, Redmond, WA.*

D.4.2.4 Cowlitz Falls: Multidisciplinary

1. Farley, J.M. , R.W. Perry, D.J. Shurleff, D.H. Feil, D.W. Rondorf, C.F. Morrill, and J.D. Serl. 2003. Migration Behavior of Juvenile Salmonids and Evaluation of a Modified Flume Entrance at Cowlitz Falls Dam, Washington, 2001. Prepared For Public Utility District No. 1. U.S. Geological Survey, Cook, Washington.*

2. Harza Northwest, Inc. 1992. Cowlitz Falls Fish Passage Alternatives. Report Submitted to Bonneville Power Administration. Harza, Bellevue, Washington.

3. Rutz, D.H. Feil, N.S. Adams, C.F. Morrill, and J.D. Seri. 2001. Test Concept to Improve Fish Guidance Using Induced Water Currents at Cowlitz Falls Dam. Contract W68SBV90053698-004.

D.4.3 Baker Reference List

D.4.3.1 Baker: Engineering Design

1. PSE. 2005. Upper Baker and Lower Baker Dam Schematics and operating data. Unpublished work.

2. WGI. 2006. Design Memorandum, Upper Baker Floating Surface Collector. Unpublished work.

3. WGI. 2006. Final design report, Upper Baker Floating Surface Collector. Unpublished work.

D.4.3.2 Baker: Biological Evaluation

1. MWH. 1999. Baker River Project Fish Facility Modernization Study. Unpublished work.

2. PSE. 1984-2006, PSE. Mark-release-recapture studies. Unpublished work.

3. PSE. 1987-2006, PSE. Juvenile outmigrant trap sampling data. Unpublished work.

4. MWH. 2002. Draft Report on the Near-Field Smolt Behavior Study in Baker Lake, Washington. Unpublished work.

5. MWH. 2002. Draft Report on Smolt Radiotelemetry Migration Study in Baker Lake, Washington. Unpublished work.

6. MWH. 2002. Draft Report on the Migration Patterns of PIT-Tagged Juvenile Salmonids in Baker Lake, Washington. Unpublished work.

7. R2 Resource Consultants. 2007. 2006 Biological Evaluation Study Report, Upper Baker Downstream Fish Passage Floating Surface Collector. Unpublished work.

8. PSE. 1987-2006. Trap sampling data, mortalities, 1987-2006. Trap sampling data includes mortalities within the holding area and in sampling activities. Data do not exist for transport to the release area. Data will be collected in the new facility, which includes stress-relief ponds. Contacts: Nick Verretto or Arnie Aspelund, PSE. Unpublished work.

D.4.3.3 Baker: Numerical Modeling

1. ENSR. 2005. Computational Fluid Dynamics Model of the Upper Baker River Project Forebay. Unpublished work.

2. ENSR. 2006. Computational Fluid Dynamics Model of the Upper Baker River Project Forebay. Unpublished work.

D.4.3.4 Baker: Physical Modeling

1. ENSR. 2005. Puget Sound Energy Baker Lake Dam Floating Surface Collector Physical Hydraulic Model Study. Unpublished work.

D.4.4 Round Butte Reference List

D.4.4.1 Round Butte: Numerical Modeling

1. Battelle. 2006. Hydrodynamic Modeling for Round Butte Dam Forebay Using Fine Grid EFDC and CENTAUR-3D CFD Models. Executive Summary prepared for Portland General Electric.

2. Khan, L. and C.E. Sweeney. 2004. Analysis of Transient Pressures in the Proposed Selective Withdrawal Tower at Pelton Round Butte Hydroelectric Project. Letter Report prepared for K. Marshall, Portland General Electric Company.

D.4.4.2 Round Butte: Physical Modeling

1. ENSR. 2007. Round Butte Dam Selective Water Withdrawal Facility Physical Hydraulic Model Studies. Final Report under preparation for Portland General Electric Company.

D.4.5 Willamette Falls Reference List

D.4.5.1 Willamette Falls: Physical Modeling

1. ENSR. 2006. Willamette Falls Fish Passage Model Studies, Final Report. Report Submitted to Portland General Electric Company. ENSR, Redmond, WA.

D.4.5.2 Willamette Falls: Multidisciplinary

1. Normandeau Associates, Inc. 2001. Final Report: Fall 2000 Evaluation of Juvenile Spring Chinook Salmon Downstream Migration at the Willamette Falls Project Under Two Passage Scenarios. Report Submitted to Fisheries/Aquatics/Terrestrial Workgroup, Issue No. DFP4 (April 30,2001). Normandeau Associates, Brattleboro, VT.

D.4.6 North Fork Reference List

D.4.6.1 North Fork: Biological Evaluation

1. Beamesderfer, R., A. Kalin, and S. P. Cramer. 2001. Analysis of PIT Tag Detections for the Clackamas River. Prepared for Portland General Electric Company.

2. BioSonics. 2004. Target Detections at the North Fork Dam Using Scientific Acoustic Techniques, Spring and Fall Studies, 2003. Prepared for the Clackamas River Project, Fish Passage Technical Subgroup.

3. BioSonics. 2005. Fish Detections at the North Fork Dam Using Scientific Acoustic Techniques, Spring and Fall Studies, 2004. Prepared for the Clackamas River Project, Fish Passage Technical Subgroup.

4. Heisey, P. G., D. Mathur, J. L. Fulmer, S. W. Adams, and T. D. Brush. 2002. Estimation of Juvenile Salmonid Spillway Passage Survival at North Fork Dam. Prepared for Portland General Electric Company and the Clackamas River Project Fish Passage Technical Subgroup.

5. Karchesky, C. M., T. D. Brush, D. D. Royer, E. J. White, M. Sharp, and B. Hanson. 2003. Final Report: Downstream Migration of Juvenile Salmonids through the North Fork Development, Clackamas River, 2002. Prepared for Portland General Electric Company and the Clackamas River Project Fish Passage Technical Subgroup.

6. Karchesky, C. M., T. D. Brush, M. M. Sharp, and D. Mathur. 2004. Final Report: Evaluation of Downstream Migration of Juvenile Spring Chinook, Coho, and Steelhead at the North Fork Development, 2003. Prepared for Portland General Electric Company and the Clackamas River Project Fish Passage Technical Subgroup.

7. Timko, M. and T. D. Brush. 2004. Final Report: Approach, Congregation Areas, and Passage of Acoustically Tagged Spring Chinook Smolts in the Forebay of the North Fork Development, Clackamas River, Oregon. Prepared for Portland General Electric Company and the Clackamas River Project Fish Passage Technical Subgroup.

D.4.6.2 North Fork: Multidisciplinary

1. Karchesky, C. M. and T. D. Brush. 2005. Final Report: Evaluation of the Experimental Fish Bypass Channel at the River Mill Development, Fall 2004. Prepared for Portland General Electric Company and the Clackamas River Project Fish Passage Technical Subgroup

D.4.7 Howard Hanson Reference List

D.4.7.1 Howard Hanson: Engineering Design

1. USACE. 2000. Draft 35% Design Documentation Report – Additional Water storage Project-Howard Hanson Dam, Green River, WA.

D.4.7.2 Howard Hanson: Physical Modeling

1. ENSR and INCA Engineers. 2003. Final Report: Howard Hanson Dam Fish Passage, 1:8 Scale Physical Hydraulic Model; Contract No. DACW57-97-D-0003, D.O No. EC03. Prepared for U.S. Army Corps of Engineers, Seattle District.

2. ENSR and INCA Engineers. 2003. Final Report: Howard Hanson Dam Fish Passage, 1:15 Scale Physical Hydraulic Model; Contract No. DACW57-97-D-0003, D.O No. EC02. Prepared for U.S. Army Corps of Engineers, Seattle District.

D.5 Miscellaneous/General Reference List

D.5.1 General: Engineering Design

1. Cada, G.F. 1998. Fish Passage Mitigation at Hydroelectric Power Projects in the United States. Editors: Jungwirth, M.,S. Schmutz, and S. Weisss. Fish Migration and Fish Bypasses. Vienna, Austria. Fishing News Books. pp. 208-219.

2. Carlson, T.J. 1998. Appendix A: Overview of Fish Passage and Protection Technologies in the Columbia River Basin.

3. ENSR and GEI Consultants. 2005. Surface Collector Concept Feasibility Study, Howard Hanson Dam, Green River. Submitted to Seattle District, U.S. Army Corps of Engineers. GEI Consultants, Inc., Lake Oswego, Oregon.*

4. Henderson, F. M. 1966. Open Channel Flow. Upper Saddle River, NJ: Prentice Hall.

5. Johnson, G., A. Giorgi, C. Sweeney, M. Rashid, and J. Plump. 1999. High Flow Outfalls for Juvenile Fish Bypasses: Preliminary Guidelines and Plans for Research and Implementation- Final Report. BioAnalysts, Inc. ENSR, INCA.*

6. Northwest Fisheries Science Center. 2000. White Paper: Passage of Juvenile and Adult Salmonids Past Columbia and Snake River Dams.*

7. Office of Technology Assessment. 1995. Fish Passage Technologies: Protection at Hydropower Facilities. U. S. Government Printing Office, Washington, D. C. OTA-ENV-641.

8. Pacific Northwest National Laboratory, BioAnalysts, ENSR, and Normandeau Associates. 2001. Design Guidelines for High Flow Smolt Bypass Outfalls: Field, Laboratory, and Modeling Studies. Final Report. Prepared for U.S. Army Corps of Engineers Portland District.*

9. Poe, T.P., M.G. Mesa, R.S. Shively, and R. Peters. Development of Biological Criteria for Siting and Operation of Juvenile Fish Bypass Systems: Implications for Protecting Juvenile Salmonids From Predation. Editor: K. Bates. Fish Passage Policy and Technology. Portland, OR. AFS.

10. R2 Resource Consultants, Inc. 1997. Report: Review of Screening Criteria and Technology for High Flow Fish Passage Systems in the Columbia River Report: Summary of Available Literature Regarding High Flow Fish Passage Systems Report: Biological Assumptions and Conceptual Study Designs.

11. R2 Resource Consultants, Inc. and Fisheries Consultants. 1997. Annotated Bibliography Regarding High Flow Dewatering Systems.

12. R2 Resource Consultants, Inc. and Fisheries Consultants. 1997. Review of Screening Criteria and Technology for High Flow Fish Passage Systems in the Columbia River. R2 Resource Consultants, Inc., Redmond, Washington.

13. Rainey, S. 1997. "Opportunity for Discovery": An Important Tool for Assessment of Surface Collection Technology Potential for Improving Juvenile Salmon Passage at Columbia River Dams.

14. Reese, L. Surface Oriented Juvenile Fishways - Hydraulic Overview. International Water Resources Engineering Conference. Seattle, WA.

15. Shively, R.S., T.P. Poe, M.B. Sheer, and R. Peters. 1996. Criteria for Reducing Predation by Northern Squawfish Near Juvenile Salmonid Bypass Outfalls at Columbia River Dams. *Regulated Rivers: Research and Management*. 12.

16. Stone & Webster. 1995. Dewatering Functional Design Criteria. Surface Bypass and Collection System Dewatering System Field Investigation. Stone & Webster, Denver, Colorado.*

17. Sverdrup and ENSR. 1998. Lower Snake River Surface Bypass and Collection System Combinations Conceptual Design Report. Final Report. Prepared for U.S. Army Corps of Engineers Walla Walla District.

18. U.S. Army Corps of Engineers, Bureau of Reclamation, and Bonneville Power Administration. 2005. 2005-2007 Implementation Plan for the Federal Columbia River Power System Endangered Species Act Updated Proposed Action. U.S. Army Corps of Engineers, Portland, OR.

19. U.S. Army Corps of Engineers, Portland District. 2006. Report on a Vortex Suppression Device.

20. Vischer, D. L. and W. H. Hager. 1998. Dam Hydraulics. London: John Wiley & Sons, Ltd.

D.5.2 General: Biological Evaluation

1. Andrew, F. J. and G. H. Geen. 1960. Sockeye and pink salmon production in relation to proposed dams in the Fraser River system. International Pacific Salmon Fisheries Commission Bulletin, XI, New Westminster, British Columbia, Canada.

2. Bates, D.W. 1964. Exploratory Research on Guiding Juvenile Salmon. U. S. Bureau of Commercial Fisheries, Seattle, WA.

3. Coutant, C.C. 1999. Think Like A Fish! Emphasizing The "Behavior" in Behavioral Guidance Systems. *Hydroreview*. 18(3).

4. Coutant, C. C. and R. R. Whitney. 2000. Fish behavior in relation to passage through hydropower turbines: a review. Trans. Am. Fish. Soc., 129: 351–380.

5. Dauble, D.D., S.M. Anglea, and G.E. Johnson. 1999. Surface Flow Bypass Development in the Columbia and Snake Rivers and Implications to Lower Granite Dam. Final Report to U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington. Battelle.*

6. Erho, M.W. 1967. Evaluation of Floating Traps for Collecting Downstream Migrating Salmonids From the Upper End of a Reservoir. Washington Department of Fisheries, Olympia, WA.

7. Erho, M.W., and G.E. Johnson. 1998. Review of Premises for Surface Bypass Development at Lower Snake and Columbia River Dams. Completion report submitted to the Corps of Engineers. July 29, 1998.

8. Faber, D. M., M. A. Weiland, and R. W. Moursund. 2001. Evaluation of three-dimensional fish behavior associated with fish passage through, around, or under prototype surface flow bypass structures. Preliminary report submitted to Portland District, U.S. Army Corps of Engineers. January 13, 2001.

9. Federal Energy Regulatory Commission, Office of Energy Projects, Division of Hydropower Administration and Compliance. 2004. Evaluation of Mitigation Effectiveness at Hydropower Projects: Fish Passage. Draft report. Washington, D. C. 20041008-0140.

10. Giorgi, A., G. Johnson, and M. Erho. 2000. Critical Assessment of Surface Flow Bypass Development in the Lower Columbia and Snake Rivers During 1995-1996M. Odeh. Advances in Fish Passage Technology. American Fisheries Society, Bethesda, Maryland. Pages 41-56.*

11. Giorgi, A.E. and J.R. Stevenson. 1995. A Review of Biological Investigations Describing Smolt Passage Behavior at Portland District Corps of Engineer Projects: Implications to Surface Collection Systems. Draft. Don Chapman Consultants, Inc., Boise, Idaho.*

12. Goodwin, R.A., J.J. Anderson, and J.M. Nestler. 2004. Decoding 3-D Movement Patterns of Fish in Response to Hydrodynamics and Water Quality for Forecast Simulation. Proceedings of the 6th International Conference on Hydroinformatics 2004. Liong, Phoon, and Babovic, eds., World Scientific Publishing Company, 21-24 June 2004. Singapore.

13. Goodwin, R. A., Nestler, J. M., Anderson, J. J., Smith, D. L., Tillman, D., Toney, T., Weber, L. J., Li, S., Cheng, J.-R., and Hunter, R. M., 2006a. "The Numerical Fish Surrogate: Converting Observed Patterns in Fish Movement and Passage to a Mechanistic Hypothesis of Behavior for Engineering Design Support", Draft Final Technical Report ERDC/EL-06, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

14. Goodwin, R. A., Nestler, J. M., Anderson, J. J., Weber, L. J., and Loucks, D. P. (2006b). "Forecasting 3-D fish movement behavior using a Eulerian-Lagrangian-agent method (ELAM)." Ecological Modelling, 192, 197-223.

15. Goodwin, R. A., Nestler, J. M., Anderson, J. J., and Cheng, J.-R. (2007). "Understanding hydrodynamics from the fish's point of view, Part I: Integrating CFD modeling, individual movement, and spatial/cognitive ecology." Proceedings of the 6th International Symposium on Ecohydraulics, 18 - 23 February 2007, Christchurch, New Zealand.

16. Nestler, J. M., Goodwin, R. A., Anderson, J. J., and Smith, D. L. (2007). "Understanding hydrodynamics from the fish's point of view, Part II: Integrating flow field distortion, sensory biology, and geomorphology." Proceedings of the 6th International Symposium on Ecohydraulics, 18 - 23 February 2007, Christchurch, New Zealand.

17. Haro, A., M. Odeh, J. Noreika, and T. Castro-Santos. 1998. Effect of Water Acceleration on Downstream Migratory Behavior and Passage of Atlantic Salmon Smolts and Juvenile American Shad at Surface Bypasses. *Transactions of the American Fisheries Society*. 127(6).

18. Hays, S.G., B.D. Leman, M.B. Dell, M.W. Erho, and D.L. Hauck. 1978. Studies of the Migrational Behavior of Salmonid Smolts in Mid-Columbia River Reservoirs and the Use of Spill to Pass Smolts Past Hydroelectric Projects. Chelan, Grant and Douglas County Public Utility Districts, Wenatchee, WA.

19. Iverson, T.K. 1999. A Scanning Split-Beam Hydroacoustic Technique for Determining the Zone of Entrainment of Juvenile Salmonids Passing Hydropower Dams. Odeh, M., Editor. Innovations in Fish Passage Technology. American Fisheries Society, Bethesda, Maryland. pp. 143-155.

20. Johnson, G.E., B.D. Ebberts, D.D. Dauble, A.E. Giorgi, P.G. Heisey, R.P. Mueller, and D.A. Neitzel. 2003. Effects of Jet Entry at High Flow Outfalls on Juvenile Pacific Salmon. *N. Amer. J. Fish. Manag.* 23.*

21. Johnson, G.E. and D.D. Dauble. 2006. Surface Flow Outlets to Protect Juvenile Salmonids Passing Through Hydropower Dams. In Press: <u>Reviews in Fisheries Science</u>.*

22. Jungwirth, M., S. Schmutz, and S. Weiss. 1998. Fish Migration and Fish Bypasses. Vienna, Austria. Fishing News Books, London.

23. Larinier, M. and F. Travade. 2002. Downstream Migration: Problems and Facilities. Editors: Larinier, M.,F. Travade, and J. Porcher. Fishways: Biological Basis, Design Criteria and Monitoring. pp. 181-207.

24. Larinier, M. 1998. Upstream and downstream fish passage experience in France, pp. 127–145. In: Fish Migration and Fish Bypasses. (Jungwirth, M., S. Schmutz, and S. Weiss, Eds.) London: Fishing News Books.

25. National Marine Fisheries Service. 1995. Reasonable and Prudent Alternative in the NMFS Biological Opinion on 1994-1998 Operation of the Federal Columbia River Power System and Juvenile Transportation Program.

26. National Marine Fisheries Service. 1998. Biological Operation of the Federal Columbia River Power System and Juvenile Transportation Program. May 14, 1998.

27. National Marine Fisheries Service. 2000. Biological Opinion on Operation of the Federal Columbia River Power System and Juvenile Transportation Program. September 2000.

28. National Marine Fisheries Service. 2004. Biological Opinion on Operation of the Federal Columbia River Power System and Juvenile Transportation Program. December 2004.

29. Thorne, R.E. and G.E. Johnson. 1993. Reviews in Fisheries Science. A Review of Hydroacoustic Studies for Estimation of Salmonid Downriver Migration Past Hydroelectric Facilities on the Columbia and Snake Rivers in the 1980s. pp. 27-56.

30. Williams, R.N., P.A. Bisson, C.C. Coutant, D. Goodman, J. Lichatowich, W. Liss, L. McDonald, P.R. Mundy, B. Riddell, and R.P. Whitney. Review of the U.S. Army Corps of Engineers' Capital Construction Program. Part II. A. Development and Testing of Surface Bypass. ISAB Report 98-7.

31. Venditti, D., D. Rondorf, and J. Kraut. 2000. Migratory behavior and forebay delay of radio-tagged juvenile fall chinook salmon in a lower Snake River impoundment. North Am. J. Fish Manage., 20: 41–52.

D.5.3 General: Multidisciplinary

1. Bisson, P. A., C. C. Coutant, D. Goodman, J. Lichatowich, W. Liss, L. McDonald, P. R. Mundy, B. Riddell, R. Whitney, and R. Williams. 1999. Review of the U.S. Army Corps of Engineers' capital construction program. Part II. A. Development and testing of surface bypass. ISAB Report 99-4 to the Northwest Power Planning Council and NMFS. February 16, 1999.

2. Goodwin, R. A., Nestler, J. M., Weber, L., Lai, Y. G., and Loucks, D. P. (2001). "Ecologically sensitive hydraulic design for rivers: lessons learned in coupled modeling for improved fish passage." Proceedings of the ASCE Specialty Conference on Wetlands Engineering and River Restoration 2001, 25 - 31 August 2001, Reno, Nevada.

3. Johnson, G.E., A.E. Giorgi, and M.W. Erho. 1997. Critical Assessment of Surface Flow Bypass Development In The Lower Columbia and Snake Rivers. U. S. Army Corps of Engineers, Portland and Walla Walla District Offices.*

4. Nordlund, B. and S. Rainey. 2000. Surface Collector Development on the Columbia and Snake Rivers: A Regional Perspective. Odeh, M., Editor. Advances in Fish Passage Technology: Engineering Design and Biological Evaluation. American Fisheries Society, Bioengineering Section, Bethesda, Maryland. pp. 13-41.

5. Odeh, M. 2000. Advances in Fish Passage Technology: Engineering Design and Biological Evaluation. American Fisheries Society, Bioengineering Section, Bethesda, Maryland.

6. R2 Resource Consultants, Inc. and Fisheries Consultants. 1997. Summary of Available Literature Regarding High Flow Fish Passage Systems. R2 Resource Consultants, Inc., Redmond, Washington.

7. Recovery team. 1995. Transcript of Snake River Salmon Recovery Team Workshop on Surface Collection/Bypass Concept Testing and Evaluation in 1995. Held Tuesday, February 7, 1995. Draft.

8. Stone, J. M. and T. R. Mosey. Biological evaluation of the Rocky Reach juvenile fish bypass system 2004. Chelan County Public Utility District, Wenatchee, WA (2004).

9. Sverdrup and ENSR. 1998. Lower Snake River Juvenile Salmon Feasibility Study, Lower Snake River, Surface Bypass and Collection System Combinations Design Report.*

10. U.S. Army Corps of Engineers. 1994. Columbia River Salmon Mitigation Analysis, System Configuration Study Phase 1, Upstream Collection and Conveyance, Technical Report, Appendix D, Walla Walla COE (April 1994 - Draft).

11. U.S. Corps of Engineers. 1995. Lower Snake and Columbia Rivers Surface Bypass and Collection Systems Prototype Development Program. Report prepared by Portland and Walla Walla Districts, U.S. Army Corps of Engineers. August 1995.*

12. Whitney, R., L. Calvin, M. Erho, and C. Coutant. 1997. Downstream Passage for Salmon at Hydroelectric Projects in the Columbia River Basin: Development, Installation, and Evaluation. Final Report.

Annotated Reference List: Sorted By Project and Discipline

D.1 Mid-Columbia River Annotated Reference List

D.1.1 Wells Reference List

D.1.1.1 Wells: Engineering Design

1. ENSR. 1994. Bathymetric Survey of Wells Hydroelectric Project Forebay. Report Submitted to Svedrup. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Douglas County
Project: Wells Dam
Type of Evaluation: Bathymetry survey of project forebay.
Goals, Objectives, and Methods: The objective of the survey was to provide more detailed bathymetric data for input into a CFD model of Wells Dam. The CFD model was developed to better understand the flow features approaching the dam site and determine their contributions to the effectiveness of fish passage at the facility.
Key Findings: Survey data are presented in 26 cross section plots.

2. Sverdrup and Parcel and Associates, Inc. 1985. Prototype Bypass Study. Report Prepared for DCPUD.

Organization: Public Utility District No. 1 of Douglas County
Project: Wells Dam
Type of Evaluation: Forebay current meter study.
Goals, Objectives, and Methods: Forebay current measurements were conducted to determine the effect of the 1985 prototype bypass system on the forebay and spillbay water velocity distribution. The bypass system was a series of solid barriers designed to fit in the forebay trashrack slots. The bottom of the barriers contained movable doors that had a maximum vertical opening of 8 feet. Ten different combinations of underflow door opening and spillway gate configuration were tested.
Key Findings: The velocity data collected for each test combination are presented in graphical and tabular format.

3. Sverdrup and Parcel and Associates, Inc. 1982. Prototype Juvenile Salmon Bypass Study. Report Prepared for DCPUD.

Organization: Public Utility District No. 1 of Douglas County
Project: Wells Dam
Type of Evaluation: Forebay current meter study.
Goals, Objectives, and Methods: Forebay current measurements were conducted to determine the feasibility of altering the hydro-combine approach flow to prevent juvenile salmon from entering the turbines. Two schemes were tested: (1) installing solid covers on the turbine intake emergency gate slots and opening the flap gate in the top leaf of the spillway gate, and (2) installing solid panels in front of the spillway to a point 30 to 40 feet below surface and opening the flap gate.
Key Findings: Velocity data at various locations upstream of the dam are presented for a range of project operations. The data were used to estimate the location shear plane between the water entering the turbine intake and passing over the spillway

D.1.1.2 Wells: Biological Evaluation

4. Johnson, G. and C. Sullivan. 1985. Summary of Hydroacoustic Run Timing and Distribution Studies of Downstream Migrant Salmon and Steelhead at Wells Dam From 1981 to 1984. Draft Report Prepared for Douglas County PUD No. 1, East Wenatchee, WA. BioSonics, Inc. Seattle, WA.

Organization: Douglas County PUD
Project: Wells Dam

Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: This study summarized research on run timing and vertical, horizontal, and diel distributions of juvenile salmonids at Wells Dam performed to support development of surface flow outlet technology. Wells Dam has a hydrocombine structure with the spillway openings directly above the turbine intakes. The SFO design involved baffling the spillway entrances to create flow fields in the surface layer of the forebay when designated spill gates were opened. This study used fixed hydroacoustic sampling of fish passage from transducers mounted at the bottom of pier noses and aimed up into the forebay immediately in front of the dam. The hydroacoustic data were complemented with hatchery release, fyke net, and dam operations data. The study concerned fish passage during the spring season.
Key Findings: Run timing was characterized by a peak in yearling Chinook passage in late April, a peak with mixture of yearling Chinook, steelhead, and sockeye in early May, and another peak in late May of juvenile sockeye salmon. Vertically, smolts were distributed deeper during night than day, and deeper during spill than no spill. Horizontally, passage was highest in the region of Turbine 3/Spill Bay 4. On a diel basis, passage rates as a whole were comparable between day and night.

5. Johnson, G.E. 1996. Fisheries Research on Phenomena in the Forebay of Wells Dam in Spring 1995 Related to the Surface Flow Smolt Bypass. Report Prepared for the U. S. Army Corps of Engineers, Walla Walla District, Walla Walla, WA. Battelle Pacific Northwest National Laboratory, Richland, WA.

Organization: CENWW funded this study; DCPUD owns and operates Wells Dam
Project : Wells Dam
Type of Evaluation: Biological evaluation -- literature review and field ACDP and hydroacoustics
Goals, Objectives, and Methods: The goal of this study was to learn why the SFO at Wells Dam is so efficient in routing salmon and steelhead smolts away from turbines. Previous work at Wells substantiated a high total project bypass efficiency. Much study in the 1980s focused on passage inside the dam (e.g., Johnson and Sullivan 1985). Although some forebay purse seine samples were taken to describe emigration characteristics, none of this work examined the dynamics of smolt density in the forebay as it related to SFB. The objectives of this study were to: 1) Consult with developers of Wells' surface flow bypass system to summarize their experience in designing a successful surface flow bypass system. 2) Synthesize existing literature to assess two fundamental assumptions about surface flow bypass systems and fish behavior in forebays: (a) Smolts are attracted to the baffle flows, i.e., they respond to water velocity gradients by moving toward the area of higher velocity (negative rheotaxis); and (b) Downstream migrant salmonids prefer not to sound to pass through a dam. 3) Collect new, detailed data to determine the association between smolt distribution and water velocity and location in Wells' forebay.
Key Findings: Objective 1 -- Discussions with people who developed SFB at Wells Dam revealed several important lessons: 1) Do not try to make fish do something they do not want to do; 2) Fish will avoid turbines if they have an alternate route of passage in the upper part of the water column at the powerhouse; 3) A small amount of spill properly baffled is as or more effective at passing fish than a similar amount of spill that is not baffled; 4) Statistically robust and precise sampling designs and analyses are required for tests and evaluations; 5) Build on the work from previous studies and experiences; capture the learning. Objective 2 The velocity assumption (smolts are attracted to the baffle flows, i.e., they respond to water velocity gradients by moving toward the area of higher velocity and display negative rheotaxis) is partially acceptable because evidence to categorically support or refute the velocity assumption is mixed. The sounding assumption (smolts prefer not to sound to pass through a dam) is acceptable because extensive data show that smolts are naturally surface oriented, they use a surface outlet when given the opportunity and right conditions, and were reluctant to sound when forced to do so. Objective 3 Simultaneous mobile hydroacoustic and ADCP surveys in the Wells forebay showed depth, not water velocity, was the most important variable in explaining variation in smolt density. The author concluded that SFO at Wells Dam is efficient because it provides an upper water column passage route where the smolts are distributed vertically. Furthermore, the hydrocombine structure also

has important effects horizontally as the entire river flow at Wells Dam moves through an area about 300 m wide. Smolts apparently are not "attracted" by SFO flows as much as they use them to "discover" an acceptable passage route in the upper water column. The author concluded SFO at Wells Dam works because it takes advantage of the synergism between the dam's hydrocombine structure and smolt behavior.

7. Johnson, G.E., C.M. Sullivan, and M.W. Erho. 1992. Hydroacoustic Studies for Developing a Smolt Bypass System at Wells Dam. *Fisheries Research*. 14.

Organization: Douglas County PUD
Project: Wells Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: The purpose of this paper was to describe the methods and results of studies aimed at developing a long-term solution to bypass smolts around turbines at Wells Dam. This solution was based on SFO technology. Taking advantage of the dam's hydrocombine structure with the spillway above the turbine intakes, SFO developers installed spill intake baffles to create presumed "attractant" flow fields in surface waters entering the dam from the forebay. In annual studies during spring and sometimes summer from 1980 to 1989, researchers used fixed hydroacoustics to compare SFO efficiencies for prototype baffle configurations and operational conditions. For a given section of the hydrocombine, SFO efficiency was estimated by: bypass passage divided by bypass plus turbine passage. The paper also includes results from a total water column fyke net sampling effort.
Key Findings: This paper summarizes the progression of research for SFO development, from baseline descriptive studies to statistical comparisons of SFO efficiency data under rigorous experimental designs. Table 2 (p. 227) provides a useful summary of the 13 SFO configurations tested and efficiency data for the prototype SFO for Wells Dam. Figure 9 (p. 233) shows the vertical distribution data by species from the total water column fyke net array. These data substantiated the potential for SFO at Wells Dam and resulted in the removal of intake screens as a smolt bypass option. A vertical slot configuration was chosen for installation project-wide at every other spill bay across the powerhouse. The 1980-1989 SFO studies at Wells Dam reported in this paper led to total project SFO efficiency was the subject of hydroaouctic studies during 1990-1992 (Skalski et al. 1996).

11. McGee, J. 1984. Juvenile Salmonid Monitoring in the Wells Dam Forebay April-May 1984. Douglas County PUD, East Wenatchee, WA.

Organization: Douglas County PUD
Project: Wells Dam
Type of Evaluation: Biological evaluation - purse seine
Goals, Objectives, and Methods: This study continued the purse seine research on forebay migration characteristics reported by Weitkamp and Neuner (1981) and McGee and Truscott (1982).
Key Findings: Migration timing by species was similar to previous years. The spatial distribution for yearling Chinook salmon showed highest CPUE along the east shore in the thalweg, as observed in 1982. The number of sockeye sampled (31) was too small to draw any meaningful conclusions. The distribution of steelhead was skewed to the thalweg area of the east forebay. This study concluded the 4-year series of purse seine studies in the forebay that provided baseline data on migration characteristics to support development of a smolt bypass at Wells Dam.

12. McGee, J. 1984. Migration Timing of Juvenile Salmonids in the Wells Dam Forebay April July 1984. DCPUD.

Organization: Douglas County PUD
Project: Wells Dam
Type of Evaluation: Biological evaluation - purse seine
Goals, Objectives, and Methods: This study continued the purse seine research on forebay migration

characteristics reported by Weitkamp and Neuner (1981) and McGee and Truscott (1982).
Key Findings: Migration timing by species was similar to previous years. The spatial distribution for yearling Chinook salmon showed highest CPUE along the east shore in the thalweg, as observed in 1982. The number of sockeye sampled (31) was too small to draw any meaningful conclusions. The distribution of steelhead was skewed to the thalweg area of the east forebay. This study concluded the 4-year series of purse seine studies in the forebay that provided baseline data on migration characteristics to support development of a smolt bypass at Wells Dam.

13. McGee, J. and K. Truscott. 1982. Juvenile Salmonid Monitoring Okanogan River and Wells Dam Forebay, April-May 1982. DCPUD.

Organization: Douglas County PUD
Project: Wells Dam
Type of Evaluation: Biological evaluation - purse seine
Goals, Objectives, and Methods: This study continued work on forebay migration characteristics reported by Weitkamp and Neuner (1981).
Key Findings: Highest catch per unit effort (CPUE) of yearling Chinook salmon was at sampling locations near the east side of the forebay in the thalweg (p. 3&12). In contrast, the highest CPUE for sockeye was at a sampling location along the west shoreline in an inundated area (p.18). The spatial distribution of juvenile steelhead was variable.

14. Olson, F.W. 1984. Depth Distribution of Juvenile Salmonids Entering the Turbine Intakes at Wells Dam. Draft Report Submitted to Douglas County PUD, East Wenatchee, WA. CH2M-Hill.

Organization: Douglas County PUD
Project: Wells Dam
Type of Evaluation: Biological evaluation - fyke nets
Goals, Objectives, and Methods: The goal of this study was to understand the vertical distribution of fish at the Wells Dam hydrocombine in order to support development of smolt bypass methods, including screen intake diversion systems. The objective was to estimate the vertical and diel distributions of fish by species inside the sampled turbine intake (not the spillway entrances above). An array of fyke nets (each 7.0 x 6.5 ft) was deployed in a frame with 3 columns and 7 rows. Samples were collected in spring (April 25-May 16) and summer (July 30-August 4).
Key Findings: For spring and summer Chinook and steelhead juveniles, 55-80% passed during night hours whereas, 39% of the juvenile sockeye salmon passed during night. Juvenile spring Chinook and sockeye salmon were distributed significantly deeper during night than day and deeper during spill than without spill. The difference in vertical distribution between day and night for steelhead and summer Chinook was not significant. In later research by DCPUD (reported by Johnson et al. 1992), the fyke frame for the turbine intake was augmented by additional fyke frame above for the spillway entrance, thereby creating a total water column array of fyke nets. This array was used to substantiate that the vertical distribution of juvenile salmonids would be conducive to SFO at Wells Dam.

15. Skalski, J.R., G.E. Johnson, C.M. Sullivan, E. Kudera, and M.W. Erho. 1996. Statistical Evaluation of Turbine Bypass Efficiency at Wells Dam on the Columbia River, Washington. *Canadian Journal of Fisheries and Aquatic Sciences*. 53(10).

Organization: Douglas County PUD
Project: Wells Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: The goal of this paper is to document total project bypass efficiency for the SFO at Wells Dam during 1990-1992. The statistical and logistical aspects of conducting a rigorous hydroacoustic assessment of fish passage are presented. Fixed hydroacoustic techniques coupled with finite sampling methods were used to estimate SFO efficiency from data collect at 25-29

transducers deployed in turbine intakes and SFO entrances.
Key Findings: During spring, SFO efficiency estimates ranged from 84 to 95% with a 3-year average of 89% (SE 3%). During summer, SFO efficiency estimates ranged from 77 to 97% with a 3-year average of 89% (SE 6%). This paper provides the most definitive data available on SFO efficiency for Wells Dam. However, it does not contain species-specific estimates.

17. Weitkamp, D. and J. Neuner. 1981. Juvenile Salmonid Monitoring Methow River, Okanogan River, and Wells Dam Forebay April-May 1981. Report Submitted to DCPUD. Parametrix, Inc.

Organization: Douglas County PUD
Project: Wells Dam
Type of Evaluation: Biological evaluation of fish migration behavior.
Goals, Objectives, and Methods: The goal of this study was to characterize juvenile salmonid migrations in the Wells Dam forebay. The objectives of the forebay research were to determine the species composition and temporal and spatial distributions of migrating juvenile salmonids in the forebay. A purse seine (500 ft long and 20 ft deep) was fished at 16 sampling locations in the forebay within 3 miles of the dam from April 10 to May 29, 1981. Vertical distribution data were not obtained.
Key Findings: Large numbers of hatchery yearling Chinook salmon were collected in the Wells Dam forebay between April 14 and 26. The highest concentrations occurred shortly (~2 d) after the release of fish from the Winthrop Hatchery. After April 27, numbers of yearling Chinook in the seine catches was low. Yearling Chinook had slightly higher concentrations in the nearshore sample sites than those in mid-reservoir. Steelhead were present from April 21 to May 13. As with the yearling Chinook salmon, the peak in abundance was associated with the upstream release of hatchery-reared fish. The data indicated that juvenile steelhead "..did not orient to the shoreline of the reservoir but remained in the maximum current area" (p. 44). Juvenile sockeye salmon were collected throughout May with the peak catch on May 13.Sockeye "..tended to travel down the center of the reservoir rather than along the shoreline" (p. 47).

18. Weitkamp, D.E., D. McKenzie, and T. Schadt. 1980. Survival of Steelhead Smolts During Passage Through Wells Dam Turbines and Spillways. Report Prepared for Douglas County PUD, East Wenatchee, WA. Parametrix, Inc., Bellevue, WA.

Organization: Douglas County PUD
Project: Wells Dam
Type of Evaluation: Passage survival of steelhead smolts through the turbine and spillway.
Goals, Objectives, and Methods: The objective of the study was to determine the survival through different passage routes (turbine and spillway) for the unique hydrocombine structure at Wells Dam. The investigators used freeze brands to mark different treatment and control groups released at the project and relied on recaptures at downstream projects to provide an estimate of route specific survival.
Key Findings: Estimates of survival through the turbines and spillway were 0.837 ± 0.045 and 1.077 ± 0.047, respectively. The survival estimate for control fish based on recoveries of released fish in the tailrace was lower than the spillway. Even though the investigators could not provide a plausible explanation for the greater survival through the spillway, the study did demonstrate the apparent difference in survival of migrant steelhead through the spillway and powerhouse.

D.1.1.3 Wells: Physical Modeling

1. Copp, H.D. and J.S. Gladwell. 1964. Hydraulic Model Studies Wells Hydroelectric Project. Volume I. Comprehensive Model Studies. Report Submitted to Bechtel. Washington State University.

Organization: Public Utility District No. 1 of Douglas County
Project: Wells Dam
Type of Evaluation: Comprehensive physical hydraulic model study of the project.

Goals, Objectives, and Methods: A physical model study was conducted to provide information for use in planning, design and operation of the project.
Key Findings: No conditions were found which would adversely affect the over-all safety or operation of the project. Several plots of forebay velocities approaching the project are presented.

2. Rudavsky, A.B. and J.R. Oberg. 1982. Two-Dimensional Model Study of Typical Hydro-Combine Section for the Wells Hydroelectric Project. Report Submitted to DCPUD. Hydro Research Science.

Organization: Public Utility District No. 1 of Douglas County
Project: Wells Dam
Type of Evaluation: Physical model study.
Goals, Objectives, and Methods: A two-dimensional model of a typical Wells Dam hydro-combine section was used to assist in determining the feasibility of altering the hydro-combine inflow pattern to prevent small fish from entering the turbines. Modifications tested included stop log slot baffles; emergency gate slot screens; guide vanes and blockage; overflow and underflow spillway gates; and trashrack plates.
Key Findings: Flow line plots showing the shear plane between the water entering the turbine intake and passing over the spillway are presented for each test conducted.

D.1.2 Rocky Reach Reference List

D.1.2.1 Rocky Reach: Engineering Design

5. ENSR. 1997. Field Calibration and Start-Up of Rocky Reach 1997 Surface Collector Prototype (SCP). Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Prototype field start-up and calibration testing.
Goals, Objectives, and Methods: The objectives of the test program were to provide calibration data required for operation of the prototype; confirm and/or refine the operational constraints predicted by the hydraulic model; and confirm that the performance of the prototype matches that of the 1:12 scale hydraulic model and that the bypass system performance criteria were met.
Key Findings: The report provides data and correlations that were required for effective operation of the surface collector throughout the bypass season.

6. ENSR. 1996. Field Calibration of Rocky Reach 1996 Surface Collector Prototype. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Prototype field start-up and calibration testing.
Goals, Objectives, and Methods: The test program had two major objectives: (1) determine the rate of flow through the surface collector bypass slot at a variety of expected unit loads and venture gate settings; and (2) provide an index of bypass flow as a function of a point velocity collected near the bypass slot. The surface collector discharge was determined by integrating the collector velocity field as measured by Ott current meters. Point velocity data were collected with a two-dimensional electromagnetic meter.
Key Findings: The report provides data that correlate the surface collector flow to both unit load and a point velocity measurement near the collector entrance.

7. ENSR. 1996. Rocky Reach Dam Juvenile Fish Bypass 1996 Surface Collection Prototype Primary

Screen Velocity Measurements. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Prototype field start-up and calibration testing.
Goals, Objectives, and Methods: The purpose of the field program was to provide calibrations for the surface collector flows and document diversion screen hydraulics and gatewell flows. Velocity data were collected using Ott current meters and a Sontek Acoustic-Doppler Current Meter.
Key Findings: The report provides data and correlations that were required for effective operation of the bypass facilities throughout the bypass season. Diversion screen velocities and gatewell flows are also presented for a range of unit loads.

8. ENSR. 1999. Rocky Reach Dam Juvenile Fish Bypass 1998 Prototype Start-Up and Calibration Results. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Prototype field start-up and calibration testing.
Goals, Objectives, and Methods: The purpose of the field program was to provide calibrations for the surface collector flows, document diversion screen hydraulics and entrance hydraulics, and document the gatewell flows. Velocity data were collected using Ott current meters and a Sontek Acoustic-Doppler Current Meter.
Key Findings: The report provides data and correlations that were required for effective operation of the bypass facilities throughout the bypass season. Diversion screen velocities and gatewell flows are also presented for a range of unit loads. Entrance velocity vectors showed that flow entering Entrance 1 came primarily from the forebay side of the entrance. Flow entering Entrance 2 came from the powerhouse side of the entrance in the upper half of the water column and from the forebay side in the lower half.

9. ENSR. 2000. Rocky Reach Dam Juvenile Fish Bypass 1999 Prototype Start-Up and Calibration Results. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Prototype field start-up and calibration testing.
Goals, Objectives, and Methods: The purpose of the field program was to provide calibrations for the surface collector flows and document diversion screen hydraulics and gatewell flows. Velocity data were collected using Ott current meters and a Sontek Acoustic-Doppler Current Meter.
Key Findings: The report provides data and correlations that were required for effective operation of the bypass facilities throughout the bypass season. Diversion screen velocities and gatewell flows are also presented for a range of unit loads

10. ENSR. 1998. Rocky Reach Dam Juvenile Fish Bypass Comparison of 1998 Prototype 1:30 Model and Field Collector Entrance Velocity Data. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Comparison of prototype and model data.
Goals, Objectives, and Methods: The report presents analyses comparing velocity data measured in

the field at Entrances 1 and 2 and comparing these same data to data acquired in the 1:30 model. The analyses were conducted to determine: (1) if there were detectable differences between velocity vectors measured in the field at the entrances, (2) whether the field data describe the upwelling observed in the field at Entrance 2, (3) if there were similar differences between entrances in the model, and (4) whether the model data are representative enough of the field data, both in average values and temporal variation, that further investigation of these issues might be carried out in the model.
Key Findings: The model measurements showed the same similarity in velocity vector magnitude and angle fluctuations between the two entrances as the field measurements. Differences at Entrance 2 associated with the upwelling phenomena visually observed in the field were not discernable. Model data did not show the same difference in average azimuth and vector magnitude of flow at the two entrances as compared to the field data. This was probably due to the difference in measurement locations in the model and field. Velocity magnitude and azimuth fluctuations in the model were about half of those measured in the field for both entrances.

12. ENSR. 2001. Rocky Reach Dam Juvenile Fish Bypass Systems Development of the 1999 Surface Collection Prototype. Final Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No.1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Engineering design and physical model studies of the juvenile fish bypass system
Goals, Objectives, and Methods: The objective of the modeling studies was to develop the hydraulic design of the prototype surface collection structure at Rocky Reach Dam (1999). The models were previously used to develop the 1998 prototype structure. The 1998 model results were then compared to the 1998 prototype biological evaluation, and the 1999 prototype design was developed. The 1:30 forebay model was used to asses the 1999 design goal and establish structural design criteria. The 1:14 sectional intake model was used to assess the 1999 design goal and establish diversion screen backing plate porosities and venturi gate operating positions.
Key Findings: Several recommended design changes were identified from the model study to mitigate fish descaling and minimized undesirable flow conditions. To minimize fish descaling at the Unit 1 intake diversion screens, the tip screen section must be fully block off, and the venturi gate opening should be used instead. At the Unit 2 intake diversion screens, model backing plates and a 16 ft venturi gate opening should be used to facilitate fish passage and minimize descaling. Descale at the intake diversion screens was determined to be depended on the component of velocity normal to the screen and the total velocity magnitude. Also, the wall nose of the SC2 entrance should be constructed to minimize flow separation and flow return. Furthermore, any structures that obstruct the momentum of the flow approaching the powerhouse face creates an area of upwelling and reverse flow.

13. ENSR. 1999. Rocky Reach Juvenile Fish Bypass Impacts of Production System Options on Forebay Hydraulics. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Physical hydraulic model investigation.
Goals, Objectives, and Methods: The purpose of the investigation was to document changes between the baseline forebay hydraulics, without any fish collection equipment on the powerhouse face, and those with optional Production System dewatering structures installed. The forebay hydraulics for the 1998 Surface Collector Prototype were documented to aid in assessment of the 1998 season results.
Key Findings: The report identifies changes in the size and center location of the forebay eddy for the various production system dewatering options investigated.

16. Sweeney, C.E., B. Christma, and D.E. Weitkamp. 1997. Update on Juvenile Fish Bypass at Rocky Reach Dam. Waterpower.

Organization: Public Utility District No.1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Engineering design of the juvenile fish bypass system
Goals, Objectives, and Methods: The objective of this paper was to present data that affect the working hypotheses that increasing the vertical acceleration of the flow line approaching the turbine intakes causes an avoidance reaction by the fish and enhancing and that using the existing forebay circulation patterns to present fish to the collector entrance will increase the probability of their using the surface collection entrance.
Key Findings: In 1997 smolts were tracked with a radio tag system in the Rocky Reach Forebay. The circulation patterns in the forebay did introduce many fish to the bypass system, however many of these fish did not chose to pass through the bypass system and went through the turbines or over the spillway instead. Also, fish moving within flow that was not directed toward the surface bypass collector did not interact with the collector entrance. It is hypothesized that fish the entered the bypass system and the later rejected the system as a bypass route were deterred by the deceleration in the collector channel.

D.1.2.2 Rocky Reach: Biological Evaluation

1. Adeniyi, R., T.W. Steig, J.E. Keister, and V. Locke. 1998. Hydroacoustic Evaluation of the Behavior of Juvenile Salmon and Steelhead Approaching the Powerhouse of Rocky Reach Dam During Spring and Summer 1997. Final Report. Report prepared for Chelan County PUD No. 1 Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Hydroacoustic evaluation of fish passage and approach behavior.
Goals, Objectives, and Methods: The objective of this hydroacoustic study was to monitor fish movement in the forebay as they approached the powerhouse and to evaluate the surface collector with the new flow restrictor. Hydroacoustic transducers were mounted on a sampling barge located in forebay on the powerhouse side of project. The flow restrictor was added to the entrance of the surface collector to increase entrance velocity and prevent fish from milling at the entrance of the surface collector, a behavior that has been observed in past studies.
Key Findings: With the flow restrictor the highest fish densities were observed in the upper part of the water column. The largest fish density observed while the flow restrictor was installed was at a tilt angle of 30° in front of and downstream of the surface collector. With no flow restrictor the highest fish densities were generally observed near the transducer, although the highest fish densities for the 75° tilt were observed farthest upstream of the surface collector. Fish density results when the flow restrictor was not installed were similar in the spring and summer. The mean fish densities were lower with the flow restrictor than without. Horizontal trajectories indicated that fish generally moved in a clockwise direction on the upstream side of the surface collector and a counterclockwise direction on the downstream side of the surface collector, converging toward the entrance of the surface collector. The trajectories also showed that the fish moved downstream along the roadway wall toward the surface collector entrance. When the flow restrictor was not installed, the fish showed a more uniform net clockwise movement upstream of the surface collector and a more pronounced counterclockwise movement toward the surface collector near the roadway wall than when the flow restrictor was installed. The vertical trajectory results from 1995, 1996, and 1997 suggest the fish were diving under the platform in 1996, when the platform was installed, as compared to when the platform was not installed (1995 and 1997). The vertical trajectory angles approaching the surface collector (directly in front of, upstream, and downstream) were relatively flat in the 1995 and 1997 results. In 1996, following the installation of a platform upstream of the surface collector, the vertical fish trajectory angles showed the fish moving

sharply downward as they approached the surface collector.

3. Adeniyi, R. and T.W. Steig. 1995. Hydroacoustic Evaluation of the Fish Passage Through Units 1-5, and the Juvenile Surface Collector at Rocky Reach Dam in the Spring and Summer of 1995. Hydroacoustics Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Fish passage and approach behavior.
Goals, Objectives, and Methods: The objective of the study was to monitor fish movement at turbine units 1-5 and the juvenile surface collector and to estimate horizontal, vertical, and diel distributions of fish passage as they entered these passage routes. Hydroacoustic transducers were mounted in front of the turbine units to monitor approach behavior and fish passage.
Key Findings: The horizontal distribution of fish passage at turbine units 1-5 varied across the powerhouse. The horizontal distribution in early spring (April 17-May 5) was different as compared to previous studies at Rocky Reach Dam where most fish passage occurred at unit 1. In early spring, unit 3 showed the highest average fish passage at 36.8 % and the lowest was observed at unit 1 (15.8%). In late spring (May 8-26), fish passage was relatively even for units 1-3 with relatively small differences in fish passage (17.8%-25.3%) observed in among those units. Previous studies have shown that unit 1 passes significantly more fish than units 2 and 3. In summer, the horizontal distribution was similar to previous studies where unit 1 passed more fish. In summer (June 23-July 6) the highest fish passage occurred at unit 1 (47.9%) and the lowest was at unit 5 (2.4%).
The average spatial distribution of fish across units 1-5 and the surface collector from May 8-26 showed that most fish were detected immediately upstream of the surface collector with 66.1% and the least occurred at unit 5 (2.3%). The results in summer showed the highest fish passage at unit 1. The results from June 23-July 6 showed the highest fish passage occurred at unit 1 with 39% and the surface collector at 29.9%. Overall, the results show that during the spring study period the proportion of fish was shifted from units 1 and 2 to the surface collector. In summer there was a smaller proportion of fish detected in front of the surface collector even though the vertical distribution patterns tended to be higher in the water column during the summer.

4. English, K.K., C. Sliwinski, J.J. Smith, J.R. Stevenson, and T.R. Mosey. 2000. Evaluation of Juvenile Spring Chinook, Steelhead, and Sockeye Migratory Patterns at Rocky Reach Dam Using Radio-Telemetry Techniques, 2000. LGL Limited, Sidney, B.C., Canada. Report prepared for Chelan County PUD No. 1 Wenatchee, WA.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Fish passage and approach behavior.
Goals, Objectives, and Methods: Radiotelemetry techniques were used to monitor the movement of radio-tagged juvenile Chinook, steelhead, and sockeye at key locations in the forebay of Rocky Reach Dam The research was directed at evaluating the performance of two prototype surface collectors (SC1 and SC2) and different configurations (midway and narrow entrance) for SC2.
Key Findings: The portion of radio-tagged fish detected near the surface that were available to be guided was 38-70% for steelhead, 21-100% for sockeye, and 0-100% for Chinook. For each species there appears to be a positive relationship between the portion guided and the portion available to be guided. The midway and narrow entrance configurations for SC2 had similar retention efficiencies within species (36-40% for Chinook and 34% for steelhead). The passage efficiencies for SC2 were lower than SC1 for Chinook, steelhead, and sockeye. The primary reason for this difference was the significantly higher retention efficiencies for SC1 (68% for Chinook and 72% for steelhead). The portion of the radio-tagged fish detected at the dam was significantly higher for Chinook in 2000 (89%) than in 1999 (71%), but very similar for steelhead and sockeye. As in 1999, comparisons of the passage

efficiencies for the narrow versus midway entrance configuration were not significantly different for Chinook, steelhead, or sockeye. Comparisons of the 1997-2000 results indicate a decrease in the percent guided (30% in 1997, 78% in 1999, and 69% in 2000) for the yearling Chinook available to be guided. For steelhead, there was an increase in the percent guided (67% in 1999 and 85% in 2000) for number available for guidance. There was a decrease in the percent guided 45% in 1999 and 10% in 2000) for the sockeye available to be guided.

5. English, K.K., R.C. Bocking, C. Sliwinski, J.R. Stevenson, and T.R. Mosey. 1999. Evaluation of Juvenile Spring Chinook, Steelhead, and Sockeye Migratory Patterns at Rocky Reach Dam Using Radio-Telemetry Techniques, 1999. Report Prepared for Chelan County PUD No. 1 Wenatchee, WA. LGL Limited, Sidney, B.C., Canada.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Fish passage and approach behavior.
Goals, Objectives, and Methods: Radiotelemetry techniques were used to monitor the movement of radio-tagged juvenile Chinook, steelhead, and sockeye at key locations in the forebay of Rocky Reach Dam. The research was directed at evaluating the performance of two prototype surface collectors (SC1 and SC2) and different configurations (midway and narrow entrance) for SC2.
Key Findings: The portion of the radio-tagged fish detected weekly near the surface that were available to be guided was low for sockeye (0-32%), intermediate for Chinook (22-36%, with the exception of one week), and generally high for steelhead (61-90%). There appeared to be a positive relationship between the portion guided and portion available to be guided. The wide and narrow entrance configuration for SC2 had similar retention efficiencies within species (60-70% for Chinook, 50% for sockeye, and 34-42% for steelhead). The lower retention efficiency for steelhead was likely related to the superior swimming capability of these fish. Passage efficiencies were lower for SC2 than SC1 for all fish. The reason for this difference was the difference in retention efficiencies for the two surface collectors. PIT-tag estimates of the portion of the steelhead in the cul-de-sac that were guided by some component of the fish bypass system were similar to those derived from the radiotelemetry study. Comparison of these independent estimates for Chinook and sockeye showed substantial differences in some weeks.
Comparisons of the 1997-1999 results indicate a substantial improvement in the percent guided (30% in 1997, and 78% in 1999) for the yearling Chinook available to be guided. There was no significant change for steelhead, there was an increase in the percent guided (61% in 1997 and 67% in 1999) for number available for guidance. There was a slight improvement in the percent guided for the sockeye available to be guided.

6. English, K.K., T.C. Nelson, C. Sliwinski, J.R. Stevenson, and T.R. Mosey. 1998. Evaluation of Juvenile Spring Chinook, Steelhead, and Sockeye Migratory Patterns at Rocky Reach Dam Using Radio-Telemetry Techniques 1998. LGL Limited, Sidney, B.C., Canada. Report prepared for Chelan County PUD No. 1 Wenatchee, WA.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Fish passage behavior using radiotelemetry
Goals, Objectives, and Methods: The goal was to evaluate the biological performance of the surface collector and screen bypass system being developed for use at Rocky Reach Dam, and use that information to design the final configuration. The objectives were to evaluate and compare two entrance locations, and two entrances of differing size (wide and narrow), and estimate fish guidance efficiency (FGE). Three species of radio-tagged smolts were released 4 km upstream from the dam. Fish distribution in the forebay and proportions using different routes were estimated.
Key Findings: Of the fish arriving at the dam 49%, 40%, and 10% of steelhead, yearling Chinook, and sockeye passed via the bypass system, respectively. Shallow migrating species (e.g. steelhead) passed

the surface collector component of the bypass system in the highest proportion. The narrow vs. wide entrance configuration did not appreciably affect the probability of remaining within the surface collector.

7. Hays, S. 1984. Determination of the Depth Distribution of Juvenile Salmonids in the Turbine Intakes at Rocky Reach and Rock Island Dams. Chelan County Public Utility District, Wenatchee, WA.

Organization: Chelan County PUD
Project: Rock Island and Rocky Reach dam
Type of Evaluation: Assessment of the depth distribution of juvenile salmonids at turbine intakes.
Goals, Objectives, and Methods: The main objective of the study was to determine the depth distribution of juvenile salmonids entering the turbine intakes at both projects. This study was necessary prior to development of a design for a prototype traveling screen deflector for testing at Rock Island and Rocky Reach dams. The District used fyke nets placed within the turbine intakes to determine the depth distribution of migrant salmonids.
Key Findings: The research showed that most juvenile salmonids pass through the upper 50-60% of the turbine intakes at both projects. All species exhibited diel patterns with more fish passing in the upper part of the intake during daylight than in darkness. Sockeye had the most distinct diel pattern with respect to depth during day and night. At Rocky Reach Dam yearling Chinook and coho were distributed higher in the intake than the other fish. At Rock Island Dam steelhead and coho were the species passing nearest the ceiling of the turbine intake.

11. Peven, C.M., A.M. Abbott, and B.M. Bickford. 1995. Biological Evaluation of the Rocky Reach Surface Collector, 1995. Chelan County PUD No. 1, Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Synthesis of fish movement and behavior studies related to the Rocky Reach surface collector.
Goals, Objectives, and Methods: The summary provides an overview of the biological studies (subsampling, video counts, and hydroacoustics) used to evaluate the surface collector. Biological evaluation of the collector in 1995 was limited to the enumeration of total passage, species composition, injury rate and behavior.
Key Findings: Descale and injury rates for fish bypassed through the surface collector were generally low (<5%). Sockeye were the predominant species captured in the spring and subyearling Chinook were dominant in summer. Hydroacoustic results showed a normal distribution of fish in the water column in front of the entrance, which suggest that the depth of the surface collector entrance is adequate. At the lower end of the powerhouse (units 1-5) horizontal fish trajectories in 1995 showed that most of the fish were in front of the surface collector throughout the migration season but less so during the summer.
During the spring migration season (26 April-15 June) about 725,000 fish were estimated to have used the surface collector. During the summer (16 June-10 August) 175,000 fish were estimated to have been passed by the surface collector. By collecting about 900,000 fish in the first year of operation of the prototype surface collector, the concept of surface collection at Rocky Reach was considered to have outstanding potential for development of a permanent bypass system.

12. Peven, C.M., T.R. Mosey, and K.B. Truscott. 1996. Biological Evaluation of the Rocky Reach Surface Collector 1996. Final Report. Chelan County Public Utility District, Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Synthesis of fish movement and behavior studies related to the Rocky Reach surface collector.
Goals, Objectives, and Methods: The summary provides an overview of the biological studies (PIT-

tag, radiotelemetry, video counts, and hydroacoustics) used to evaluate the surface collector.
Key Findings: Descale and injury rates for fish bypassed through the surface collector were generally low (<5%). Yearling Chinook were the predominant species captured in the spring and subyearling Chinook were dominant during the summer. Hydroacoustic results showed that most fish were in the upper layers of the water column in front of the entrance, which suggest that the depth of the surface collector entrance is adequate. Horizontal fish trajectories in 1996 showed that the distribution of fish in front of the surface collector fluctuated throughout the season. The new sloping wall and floor extension affected the direction of water flow and as a result, possibly the fish distribution in front of the collector. Radiotelemetry results showed that juvenile salmonids migrated along the west shore and then moved across to the powerhouse and eventually ended up near the surface collector entrance. Many of the radio-tagged fish that entered the surface collector failed to go all the way through and passed via another route. Further investigation determined that the entrance velocity profile was probably not conducive to passing fish.
The PIT tag study showed that about 10% of the tagged steelhead and Chinook used the surface collector. The combined collection efficiency for the surface collector and the screen bypass system in Unit 1 was 20 to 30 percent.

15. Skalski, J.R., R. Townsend, J. Lady, A.E. Giorgi, J. R. Stevenson, and R. D. McDonald. 2002. Estimating Route-Specific Passage and Survival Probabilities at a Hydroelectric Project From Smolt Radiotelemetry Studies. *Canadian Journal of Fisheries and Aquatic Sciences. 59: 1385-1393*.

Organization: Chelan County PUD
Project: All Projects
Type of Evaluation: Statistical and experimental design to estimates route specific survival at hydroelectric projects.
Goals, Objectives, and Methods: The purpose of the paper was to describe the adaptation of radiotelemetry techniques and statistical models for the specific purpose of providing detailed information on route-specific passage and survival probabilities of salmonids smolts through hydroprojects.
Key Findings: The paper describes the methods and analysis used to conduct a radiotelementry study by way of detailed examples from projects in the mid-Columbia region. The investigators demonstrated that route-specific survival model (RSSM) and the paired release-recapture model both provide precision estimates of pool, dam, and project survival. The RSSM has the additional benefit of estimating routed specific passage, which is needed to evaluate the performance of bypass systems in order to improve downstream passage at Columbia and Snake river projects.

16. Steig, T.W. 1993. Hydroacoustic Evaluation of Juvenile Salmon and Steelhead Approaching Units 1-5 at Rocky Reach Dam During the Summer of 1992. BioSonics, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Fish passage and behavior.
Goals, Objectives, and Methods: The objective of the study was to monitor fish passage at turbine units 1-5 at Rocky Reach Dam and to estimate the horizontal, vertical, and diel distributions of fish passage as they approached and entered these turbine units. Hydroacoustic transducers were mounted in front of the turbine units to monitor approach behavior and fish passage.
Key Findings: In this study investigators found that the horizontal distribution of fish indicated differences in fish passage distribution across the powerhouse at Rocky Reach Dam. The majority of fish passage occurred at units 1 and 2 with 73% passing during the entire summer study. Beyond turbine unit 3, fish passage dropped dramatically to a low of 3% at unit 5. During periods when units 1-5 were operating a majority of the time, units 1 and 2 passed 79% of the fish. Unit 2 passed 74% of the fish when units 2-5 were operating. When units 3-5 were in operation, unit 3 passed 72% of the fish.

The vertical distributions were similar between the turbine units with units 4 and 5 showing a slightly deeper distribution as compared to the other units. Fish velocity in the forebay increased with depth, which agrees with the increase in forebay water velocity at depth. During the entire study period (65 days) hourly peak fish passage occurred at 1500 h and at 0000 h (midnight). Passage time were nearly split with 45% of the fish passing during nighttime hours (1900-0700) and 55% passing during the daytime hours (0700-1900).

17. Steig, T.W. 2001. Review of Acoustic Tag Study Results at Rocky Reach and Rock Island Dams From 1998 Through 2001. Report Prepared for Chelan County PUD No. 1 Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Chelan County PUD
Project: Rocky Reach and Rock Island dams
Type of Evaluation: Brief review of behavior of the behavior exhibited at the District's projects.
Goals, Objectives, and Methods: The review provides a brief summary of the findings from acoustic tag studies that occurred over a 4-year period. The investigators tagged juvenile Chinook and steelhead to determine the movements and behavior near the projects.
Key Findings: The studies at Rocky Reach Dam showed that Chinook and steelhead exhibited various swimming behaviors (milling and straight path) near different passage routes (spill, surface collector, and powerhouse). The horizontal passage distribution across the project was summarized for Chinook (spillway 14%, turbine units 47.6%, and surface collectors 38.4%) and steelhead (spillway 9.8%, turbine units 49.7%, and surface collectors 40.5%). At Rock Island Dam the study was more of a pilot or feasibility study that showed favorable detection rates at the project (range 74-100% per release group) and a total detection rate 89.5%. The study also demonstrated that a majority of the Chinook tagged passed on the Powerhouse No. 2 side (82.3%) of the dam compared to the Powerhouse 1 side (17.7%). The study also demonstrated that the average residence time from release to passing the dam was 91.9 hours (3.8 days) and tag tests showed that average acoustic tag life was 18.2 days.

20. Steig, T.W., J.W. Horchik, and M.A Timko. 2001. Monitoring Juvenile Chinook and Steelhead Migration Routes With Acoustic Tags in the Forebay of the Powerhouse and Spillway of Rocky Reach Dam in 2000. Hydroacoustic Technology Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1, Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Acoustic evaluation of fish movement and passage in the forebay of Rocky Reach Dam.
Goals, Objectives, and Methods: The objective of the study was to monitor the migration routes of juvenile salmonids during their passage through the forebay of the powerhouse and spillway at Rocky Reach Dam. The investigators used acoustic tagged fish Chinook and steelhead to monitor the movements and passage at Rocky Reach Dam. There were two powerhouse operational configurations tested. Surface collector 2 was configured with a half-open and narrow entrance. The half-open entrance was about 33 ft wide at the upstream opening and the narrow entrance was about 20 ft wide.
Key Findings: The majority of tagged fish passed through the powerhouse and surface collectors. There was 86% of the Chinook passed through the powerhouse and surface collectors, and 14% passed through the spillway, whereas 90% of the steelhead passed through the powerhouse and surface collectors, and 10% passed through the spillway. The proportion of fish passage through the various locations showed surface collector 1 passed the largest proportion with 21% for Chinook and 36% for steelhead. Surface collectors 1 and 2 (combined) passed 38% of Chinook smolts and 50% of steelhead smolts. Units 1 and 4 passed the next largest proportion of fish. Unit 1 passed 8% Chinook and 15% steelhead, and Unit 4 passed 9% Chinook and 7% steelhead.
Surface Collectors 1 and 2 guided 41% of Chinook smolts during the half-open configuration as compared to 47% during the narrow entrance configuration. For steelhead surface collectors 1 and 2

guided 61% and 49% of the steelhead smolts with the half-open and narrow configurations, respectively. Overall, the half-open entrance configuration passed a slightly greater proportion of both Chinook and steelhead (52%) as compared to the narrow configuration (48%).
Chinook smolts that passed in surface collector 2 exhibited almost equal milling and straight path behavior. At surface collector 1 the Chinook exhibited primarily milling behavior prior to passage. Steelhead smolts exhibited primarily milling behavior prior to passing into surface collectors 1 and 2.

22. Steig, T.W., P. A. Nealson, K. K. Kumagai, L. S. Brown, G.W. Tritt, K.C. Molitor, J. W. Horchik, M.A. Timko, J.C. Sweet, and C. P. Mott. 2006. Route Specific Passage of Juvenile Steelhead, Chinook, and Sockeye Salmon Using Acoustic Tag Methodologies at Rocky Reach and Rock Island Dams in 2005. Report Prepared for Chelan County PUD No. 1, Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Acoustic evaluation of route specific fish passage at Rocky Reach Dam.
Goals, Objectives, and Methods: Acoustic tagged steelhead, yearling Chinook, and sockeye were released in several replicates to evaluate fish passage behavior at the dam. The objective of the study was to estimate route specific passage (RSP) at the project in order to evaluate the success of current measures to increase fish survival. As part of the evaluation, investigators compared RSP during spill and non-spill periods.
Key Findings: Route specific passage through the surface collector for steelhead, yearling Chinook, and sockeye was 68%, 32%, and 31%, respectively. Compared to the surface collector, fish passage through turbine units (3-11) was lower for steelhead (18%) and yearling Chinook (19%) but not for sockeye (43%). Fish passage at the spillway was the lowest for all species (2% steelhead, 3% yearling Chinook, and 2% sockeye). Turbine units 1-2 passed 6%, 14%, and 8% for steelhead, yearling Chinook, and sockeye, respectively. When testing spill versus non-spill periods, steelhead and yearling Chinook showed higher surface collector passage rates during spill than during non-spill periods. Passage rates at units 1-2 decreased for steelhead and Chinook during spill periods and for all tagged species through units 3-11 during spill periods compared to non-spill periods.
At Rock Island Dam, fish passage efficiency was highest for yearling Chinook (0.362), followed by sockeye (0.290), hatchery steelhead (0.219), and run-of-river steelhead (0.201). The majority of run-of-river steelhead passed via Powerhouse 2 (79%), followed by spillway 2 (19%), and relatively few through powerhouse 1 and spillway 1 (1% each). The passage of hatchery steelhead at powerhouse 2 (77%), spillway 2 (20%), powerhouse 1 (1.5%), and spillway 1 (2%) was similar to run-of-river steelhead. The majority of yearling Chinook smolts also passed via powerhouse 2 (60%), a lesser percentage via spillway 2 (34%), and relatively small numbers through powerhouse 1 (3%) and spillway 1 (2%). Sockeye passed Rock Island Dam mostly through powerhouse 2 (70%) and spillway 2 (28%) and few passed powerhouse 1 (1%), and spillway 1(1%).

23. Steig, T.W., P.A. Nealson, K.K. Kumegai, J.W. Horchik, C.P. Mott, and J.C. Sweet. 2006. Route Specific Passage of Juvenile Chinook, Steelhead, and Sockeye Salmon Using Acoustic Tag Methodologies at Rocky Reach and Rock Island Dams in 2004. Report Prepared for Chelan County PUD No. 1, Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Chelan County PUD
Project: Rocky Reach and Rock Island dams
Type of Evaluation: Acoustic evaluation of route specific fish passage.
Goals, Objectives, and Methods: Acoustic tagged steelhead, yearling Chinook, subyearling Chinook, and sockeye were released in several replicates to evaluate fish passage behavior at the dam. The objective of the study was to estimate route specific passage (RSP) at their projects in order to evaluate the success of current measures to increase fish survival. As part of the evaluation, investigators compared RSP during spill and non-spill periods.

Key Findings: Passage at Rocky Reach Dam via the surface collector for yearling and subyearling Chinook, steelhead and sockeye was 27%, 25%, 67%, and 38%, respectively. Chinook smolts passed through Units 3-11 (29%) followed by unguided Units 1-2 (27%), spillway (12%), and the bypass screens at Units1-2 (6%). Sub-yearling Chinook passed through via Units 3-11 (32%), followed by unguided Units 1-2 (27%), spillway (9%), and bypass screens in Units 1-2 (6%). For steelhead, passage was 13% at Units 3-11, 11% unguided Units 1-2, 5% the spillway, and 4% Units 1-2 bypass screens. For sockeye 38% passed Units 3-11 followed by unguided Units 1-2 (12%), and spillway (11%), and bypass screens at Units 1-2 (1%). During spill and non-spill conditions, steelhead passage at the surface collector was 66% and 69%, respectively. During non-spill 26% of yearling Chinook passed the surface collector compared to 27% during spill periods.
At Rock Island Dam the passage distribution for yearling Chinook was primarily through powerhouse 2 (57%), spillway 2 (37%), powerhouse 1 (4%), and spillway 1 (2%). The majority of steelhead passed via Powerhouse 2 (82%) followed by spillway 2 (17%), powerhouse 1 (2%), and spillway 1 (0.1%). Sockeye passed in highest proportion at spillway 2 (45%), followed by powerhouse 2 (30%), powerhouse 1 (15%) and spillway (1%). Sub-yearling Chinook estimates indicated that powerhouse 2 passed 33% and powerhouse 1 passed 29% of the species group in 2004. Spillways 2 and 1 passed smaller proportions by route, 24% and 14% respectively. Seasonal FPE at Rock Island Dam was greater for sockeye (0.550) than for yearling Chinook (0.386), sub-yearling Chinook (0.376), and steelhead (0.167) indicating higher rates of bypass via the spillway.

24. Steig, T.W. and R. Adeniyi. 1999. Hydroacoustic Evaluation of Fish Passage Through the Powerhouse and Surface Collectors at Rocky Reach Dam in the Spring of 1998. Final Report. Hydroacoustics Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Fish passage behavior using hydroacoustic systems.
Goals, Objectives, and Methods: The objective of the study was to monitor juvenile salmon and steelhead during the spring outmigration and evaluate the effectiveness of the two surface collectors as bypass alternatives. Hydroacoustic technology was used to monitor movement in the powerhouse forebay area of the dam.
Key Findings: The horizontal distribution of fish passage across the dam showed the largest proportion of fish were detected at SC1 and SC2 with 45.7% and 21.8%, respectively. The lowest fish passage for the entire study was seen at unit 11 (0.6%). In 1998, fish passage through units 1-3 was lower (8.6%) than previous years (36.7% in 1996 and 42.1% in 1997). In 1990, prior to installation of the surface collectors, units 1-3 use to pass 70-75% of the fish passed through the powerhouse. In this study that proportion has dropped to 26.5% (1998) which suggests that fish that would have passed through units 1-3 now pass through SC1, SC2, and units 1-3.
Tests of the low velocity (wide) and high velocity (narrow) entrance configurations showed that the proportion of fish detected at SC1 were higher for the low velocity entrance (50.8%) as compared to high velocity entrance (40.6%). These entrance configurations at SC1 did not affect fish passage at SC2. However, the percentage of fish passage increased for each of the first 5 units during periods when the high velocity entrance was installed. This suggests that the high velocity configuration did not improve the fish guidance efficiency of SC1 and may have discouraged fish from using SC1.
The vertical distributions for fish at SC1 and SC2 showed a normal distribution with peak passage at 12-27ft depth. The vertical distribution for the different entrance configurations at SC1 showed virtually no difference.

25. Steig, T.W. and R. Adeniyi. 1995. Hydroacoustic Evaluation of the Behavior of Juvenile Salmon and Steelhead Approaching the Powerhouse in the Forebay of Rocky Reach Dam During 1995. Hydroacoustic Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Fish passage and approach behavior.
Goals, Objectives, and Methods: The objective of the study was to monitor fish movement in the forebay as they approached the powerhouse and to estimate the densities, trajectories, velocities and acoustic target strength of the fish in the forebay of Rocky Reach Dam. Hydroacoustic transducers were mounted on a sampling barge located approximately in the middle of the forebay on the powerhouse side of Rocky Reach Dam to monitor approach behavior and fish passage.
Key Findings: Average horizontal fish trajectories displayed in the forebay showed that fish moved in a clockwise direction around the sampling barge. Random swimming behavior was observed in a large area in the center of the south end of the forebay. This circular pattern of fish movement was centered roughly 40 ft directly south of the sampling barge toward the roadway wall. In the forebay, fish moved downstream toward the powerhouse and the surface collector and when the fish got within the 10 ft of the surface collector, they would move directly toward and move past the surface collector entrance. Once past the entrance, the fish would proceed in a clockwise circular pattern along the roadway wall.
The vertical trajectories suggest that fish started diving about 50-60ft in front of the surface collector at a water depth of about 25-30 ft. This suggests that fish detected in this area continued diving below the surface collector and entered the turbine intakes and not the surface collector.
Analysis of fish densities in the forebay and fish passage suggested a peak build up of fish in the forebay leads to a peak in fish passage 3 hours later at the surface collector and 4 hours later at the powerhouse.

26. Steig, T.W. and R. Adeniyi. 1997. Hydroacoustic Evaluation of the Behavior of Juvenile Salmon and Steelhead Approaching the Powerhouse of Rocky Reach Dam During Spring and Summer 1996. Final Report. Hydroacoustic Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Fish movement and behavior using hydroacoustic technology
Goals, Objectives, and Methods: A sampling barge placed in the forebay of the project was used as a fixed location to mount horizontal scanning transducers to monitor fish movement during spring and summer. The objective of study was to monitor fish movement in the forebay as they approached the powerhouse and to evaluate the platform upstream of the surface collector. The platform was installed in 1996 in an effort to improve the fish passage efficiency of the surface collector. Specific objectives included estimating the densities, trajectories, velocities, and acoustic target strength of the fish in the forebay of the dam.
Key Findings: This behavior study showed that fish in the forebay of the project in front of the powerhouse traveled in a clockwise direction for both spring and summer migrants. During both sampling periods fish moved downstream parallel along the powerhouse wall toward the surface collector. However, during the spring once the fish got past the surface collector entrance they tended to mill along the roadway wall while during the summer no milling behavior was detected. In this study with the installation of the platform upstream of the surface collector, fish moved sharply downward as they approached the surface collector compared to fish trajectories observed in 1995 where the fish showed a relatively flat movement pattern as they approached the surface collector.

27. Steig, T.W. and R. Adeniyi. 1996. Hydroacoustic Evaluation of the Fish Passage Through Units 1-11, Spillways 3-5 and the Surface Collector at Rocky Reach Dam in the Spring and Summer of 1996. Hydroacoustic Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Fish passage and behavior.

Goals, Objectives, and Methods: The objective of the study was to monitor fish passage at turbine units 1-11, spillways 3-5, and the surface collector using hydroacoustic technology. The primary objectives to determine run timing of juvenile salmon and steelhead and to estimate horizontal, vertical, and diel distributions of fish passage as they entered the target areas.

Key Findings: The horizontal distribution of fish passage across the dam showed that most fish were detected at the surface collector during each of six sampling time periods. The proportion of fish detected at the surface collector ranged from 22.7% to 53.2%. The average spring and summer proportion of fish detected at the surface collector was 26.8%. For the study period, fish passage through the turbine units varied from 0.0% (units 9 and 11) to 29.6% (unit 1). The average fish passage through turbine units across all time periods varied from 0.2% (unit 11) to 14.8% (unit 1). Fish passage at three of the monitored spill gates ranged from 0.1% to 3.0%. The average spring and summer spillway fish passage varied from 0.8% to 1.6%. However, fish passed through unmonitored gates because of high river flows during the spring study.

The hourly proportion of fish passage showed the highest proportion of fish detected at the surface collector occurred between 0800-0900 h and the lowest fish passage occurred between 0000-0200 h. There was no consistent peak fish passage observed at turbine units or spill gates. The spring and summer peak daily passage was observed on May 24 and July 2, respectively. At the surface collector the majority of the fish were detected in the middle of the water column while the least were detected at the bottom and top.

29. Steig, T.W., R. Adeniyi, and V. Locke. 1997. Hydroacoustic Evaluation of the Fish Passage Through the Powerhouse, the Spillways, and the Surface Collector at Rocky Reach Dam in the Spring and Summer of 1997. Hydroacoustic Technology, Inc. Seattle, Washington, Report prepared for Chelan County PUD No. 1 Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Hydroacoustic evaluation of fish passage behavior.
Goals, Objectives, and Methods: The objective of the study was to monitor juvenile salmon and steelhead to determine the effectiveness of the surface collector and spillway as bypass alternatives.
Key Findings: The horizontal distribution of fish passage across the dam showed that the highest proportion of fish was detected at the surface collector and Unit 2. Higher fish passage was observed at turbine units 1-3. During the study few fish passed through turbine units 5-11 (range, 0.8-5.8%). There were even fewer fish detected at the spillway with the average fish passage ranging from 0.03% to 2.7%. The mean daily percent fish passed through the spillway was 16.8% and the daily average water spilled was 31.1%. During the summer mean daily fish passage was 13.4% and the daily average water spilled was 21.6%. During the spring the daily percentage of guided fish ranged from 37.1% to 89.6% with an average daily of 67.6%. In summer the values were lower and ranged from 12.9% to 79.2% with an average daily of 53.1%.

Fish behavior near the surface collector showed that for both spring and summer 77.1% of the fish were moving toward the collector and 21.6% moved away while 1.3% could not be determined. The middle portion of the surface collector showed the fewest number of fish moving away from the surface collector, while the lower portion of the collector showed the greatest number of fish. Observations with the flow restrictor in showed significantly more movement toward the collector than when it was out. Vertical distribution with the flow restrictor in showed that fish were more evenly distributed in the water column when they moved toward the collector. Fish were more concentrated near the surface as they entered the surface collector when the restrictor was out.

30. Stevenson, J.R., A.E. Giorgi, W.R Koski, K.K English, and C.A. Grant. 1997. Evaluation of Juvenile Spring Chinook and Steelhead Migratory Patterns at Rocky Reach and Rock Island Dams Using Radio Telemetry Techniques, 1996. Report Prepared for Chelan County PUD No. 1 Wenatchee, Washington. BioAnalysts, Inc., Redmond, Washington.

Organization: Chelan County PUD
Project: Rocky Reach and Rock Island dams
Type of Evaluation: Radiotelemetry evaluation of passage behavior and prototype surface collector
Goals, Objectives, and Methods: The investigators used radiotelementry to monitor the passage of juvenile spring Chinook and steelhead. At Rocky Reach Dam the objective of the research was directed at evaluating the performance of the surface collector and smolt behavior associated with different entrance configurations. At Rock Island Dam the objectives of the research were directed at evaluating the passage of smolts at the project.
Key Findings: Passage at the Rocky Reach Dam for steelhead was 23%, 38%, 8%, and 31% for the spillway, powerhouse, gatewell collection system, and surface collector. At those locations, Chinook passed in the following proportions, 33%, 60% 3%, and 4%, respectively. For steelhead, the wide surface collector entrance configuration (entrance velocity of 2.8 fps and a volume of 1,900 cfs) was more attractive than the narrow configuration (entrance velocity 5.4 fps and volume of 1,100 cfs). The surface collector retained about 42.9% to 66.8% of the steelhead that entered the surface collector under the wide configuration. Based on season wide estimates there were less Chinook that encountered (10.8%) but the surface collector retained more Chinook (88.9%) once they had entered. The surface collector entrance location was favorable to steelhead than Chinook. Most Chinook passed at locations upstream from the surface collector compared to steelhead. Spill was more effective at passing Chinook than steelhead with spill efficiency estimated at 0.98 and 0.69, respectively. In addition, fish guidance efficiency through the gatewell collection system (units 1 and 2), which is close to the surface collector was 33.3% for Chinook and 56.7% for steelhead.
At Rock Island Dam fish passed predominantly through the powerhouses (1& 2) at Rock Island Dam although increased spill tended to increase the proportion of fish through the spillways. Overall, the proportion of steelhead through powerhouse 1 (33%), and powerhouse 2 (29%) was greater than that observed at spillway 1 (19%) and spillway 2 (19%). For Chinook fish passage was greatest through powerhouse 1 (43%) and powerhouse 2 (38%), followed by spillway 2 (12%) and spillway 1 (7%). The percentage of fish passing Rock Island Dam through the spillway was skewed towards increased passage during the high spill periods compared to the low spill periods. During low spill periods, 27 % of the steelhead and 16% of the Chinook passed, but during high spill steelhead increased to 50% and Chinook passage increased to 27%.

31. Stevenson, J.R., J.R. Skalski, P. Westhagen, and A.E. Giorgi. 2004. Fish Passage Efficiency of Juvenile Yearling and Subyearling Chinook, Steelhead and Sockeye at Rocky Reach and Rock Island Dams, 2003: Telemetry Investigation. Chelan County PUD, Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Evaluation of Rocky Reach fish passage efficiency using radiotelemetry.
Goals, Objectives, and Methods: Radio-tagged yearling Chinook, subyearling Chinook, steelhead, and sockeye were released upstream from the project and were monitored as they passed downstream through the dam. The objective of the study was to identify route of passage for migrant smolts in order to evaluation the performance of fish bypass systems (surface collector, and unit 1 and 2 diversion screens) and spill effectiveness at the project. Fish passage efficiency (FPE) is the proportion of study fish that pass a particular bypass system and fish bypass efficiency (FBE) is the proportion of study fish that pass the surface collector and diversion screens combined. Spill passage efficiency is the proportion of fish passing the project via the spillway relative to the volume of water spilled.
Key Findings: Rocky Reach had low estimates of FPE for sockeye and subyearling Chinook but passage performance through the bypass system was relatively high for steelhead and yearling Chinook. The FPE for yearling Chinook, steelhead, sockeye, and subyearling Chinook was 66%, 68%, 31%, and 42%, respectively. The FBE was 53% for yearling Chinook, 58% for steelhead, 17% for sockeye, and 37% for subyearling Chinook. Spill was an ineffective (< 1.0) method for passing fish at Rocky Reach Dam. Spill efficiencies observed were low for yearling Chinook, steelhead, sockeye, and subyearling Chinook were 0.67, 0.50, 0.58, and 0.33, respectively.

Rock Island had low estimates of FPE for steelhead and subyearling Chinook but passage performance through the bypass system was relatively high for sockeye and yearling Chinook. The FPE for yearling Chinook, steelhead, sockeye, and subyearling Chinook was 47%, 36%, 46%, and 14%, respectively. Spill was an effective (> 1.0) method for passing all fish except subyearling Chinook at Rock Island Dam. Spill efficiencies exceeded 1.0, for yearling Chinook (2.36), steelhead (1.79), and sockeye (2.28), but were low for subyearling Chinook (0.68).

D.1.2.3 Rocky Reach: Physical Modeling

1. ENSR. 1995. Hydraulic Model Studies of Downstream Juvenile Fish Bypass Systems at Rocky Reach Dam Forebay Field Data Collection, Model Preparation, and Investigation of Diversion Screen System for 1994 Prototype Tests. Final Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Intake screen hydraulic performance evaluation using both field and physical model data.
Goals, Objectives, and Methods: The objectives of the study were to: (1) collect forebay velocity data necessary to calibrate a physical model of the powerhouse forebay; (2) construct and calibrate a physical model of the powerhouse forebay; (3) use the physical model to evaluate the performance of the existing intake screen configuration and make recommendations for improved performance; and (4) use field velocity measurements to confirm the results obtained from the physical model.
Key Findings: The report contains a comprehensive set of forebay velocity data that was used to calibrate both physical and numerical models used in the development of surface bypass alternatives at the project.

2. ENSR. 1998. Hydraulic Model Studies of Downstream Juvenile Fish Bypass Systems at Rocky Reach Dam: Development of the 1998 Prototype. Final Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Facility design utilizing physical models.
Goals, Objectives, and Methods: The purpose of the work described in the report was development and documentation of the hydraulic design features of the 1998 Prototype. The report summarizes the key components of the 1998 Prototype and presents the modeling tasks undertaken in developing the design.
Key Findings: A trapping entrance was designed to meet the criterion that all entrance throat velocities be greater than 7.0 fps at both surface collector entrances. The design required the addition of a “skirt” below Entrance 1.

3. ENSR. 1997. Rocky Reach Dam Juvenile Fish Bypass 1:12 Scale Modeling of 1997 Surface Collector Prototype Primary Screen and Bypass Channel. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Surface collector hydraulic performance evaluation using physical model data.
Goals, Objectives, and Methods: Analysis of the 1996 fish guidance and hydraulic performance of the Surface Collector Prototype (SCP) revealed areas for improvement. A model study was conducted to evaluate the ability of potential design changes to improve the hydraulic performance of the SCP. The model study was also used to explore alternative entrance configurations to allow prototype testing of

varying collector entrance flow rates and velocities.
Key Findings: The model study resulted in several design change recommendations intended to improve the hydraulic performance of the SCP. The study also determined the best higher velocity entrance alternative for prototype testing.

4. ENSR. 1998. Rocky Reach Dam Juvenile Fish Bypass 1996 Base Model Tests. Letter Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Surface collector hydraulic performance evaluation using physical model data.
Goals, Objectives, and Methods: The objective of the study was to obtain basic hydraulic data to support the design of a permanent fish bypass surface collector. Physical model data were collected to determine the hydraulic influence of an extended floor upstream of the surface collector entrance with and without guide walls directing the flow.
Key Findings: The hydraulic influence of the extended floor was evaluated with respect to size, strength and location of the forebay eddy; the flow lines along the powerhouse and approaching the surface collector entrance; the change in the collector's zone of influence; and forebay velocities

5. ENSR. 1998. Rocky Reach Dam Juvenile Fish Bypass Systems: Outfall Site Selection and Documentation. Final Report. Prepared for Public Utility District No. 1 of Chelan County. ENSR, Redmond, WA. ENSR document no. 1394-006-701.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Surface bypass outfall site selection and documentation.
Goals, Objectives, and Methods: The objective of the study was to locate suitable juvenile bypass system outfall sites below the dam using a 1:100 scale physical model of the tailrace based upon siting criteria established by the design team. The model was used to gather detailed velocity data throughout the tailrace, identify potential predator habitat, and track the dye plume of potential outfall locations.
Key Findings: A range of suitable outfall sites in the tailrace were identified. The District used overall bypass project considerations to select two specific sites within this range for full documentation. The two sites met the established outfall siting criteria for the full range of anticipated project operations.

6. ENSR. 2001. Rocky Reach Dam Juvenile Fish Bypass Systems Permanent Intake Screen and Surface Collector Design Development and Documentation. Final Report Submitted to Public Utility District No. 1 of Chelan County, Washington. ENSR, Redmond, WA.

Organization: Public Utility District No. 1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Hydraulic design of the permanent fish bypass facilities.
Goals, Objectives, and Methods: The objectives of the study were to develop the hydraulic design features of the intake screen and surface collection facilities and document their hydraulic performance using a pair of physical hydraulic models. The design of the facilities targeted several performance goals that were based upon information relating fish guidance, descale, and injury to project flow conditions obtained through many years of prototype testing at the project.
Key Findings: The hydraulic performance of the facilities was documented for a range of project operations.

8. Sweeney, C.E., Christman, B., and Weitkamp, D.E. 1995. Surface Attraction Fish Bypass at Rocky Reach Dam. Waterpower.

Organization: Public Utility District No.1 of Chelan County
Project: Rocky Reach Dam
Type of Evaluation: Physical modeling of the juvenile fish bypass system
Goals, Objectives, and Methods: The objective of this paper was to describe of the attraction system, migrating salmon and trout behavior, and the hydraulic characteristics at the Rocky Reach forebay. Also, the tools used to develop the surface fish attraction prototype design were discussed.
Key Findings: A 1:30 forebay model and 1:15 attractor and screen system model were used to optimize the Rocky Reach surface collector design. The structure orientation, attractor slot location and wall configuration, and attractor zone of influence were determined based on the model results. The structure was orientated to promote the use of eddying flow patterns to present fish to the attractor entrance on multiple passes. The slot and wall configuration was adjusted to minimize vertical movement of flow down toward the turbine intakes, until directly before the intake where there was a sudden acceleration. The zone of influence was determined with dye injections. In addition, the models provided the deign engineers with hydraulic loading information.

D.1.2.4 Rocky Reach: Multidisciplinary

1. District Staff, et. al. 1995. Rocky Reach Dam and Rock Island Dam Fish Bypass Annual Project Team Report for Period Ending December 1994. Summary Report Prepared for Public Utility District No. 1 of Chelan County, Washington.

Organization: Public Utility District No. 1 of Chelan County
Project: Rock Island and Rocky Reach Dams
Type of Evaluation: First annual report from the Rock Island and Rocky Reach juvenile fish bypass project design team.
Goals, Objectives, and Methods: The report summarizes the developments made on the fish bypass designs and planning at both projects during 1993 and 1994. It documented the current project status, communicated proposed courses of action for future progress and the logic applied in adopting these courses, reported progress relative to compliance with the Federal Energy Regulatory Commission Agreements, and provided a vehicle for the parties involved in the project to communicate this information.
Key Findings: The document outlines the basis for development of a surface bypass facility at Rocky Reach Dam.

3. Mosey, T.R., K.G. Murdoch, and B.M. Bickford. 2000. Biological and Hydraulic Evaluation of the Rocky Reach Fish Bypass System 1999. Chelan County PUD No. 1, Wenatchee, WA.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Evaluation of Rocky Reach bypass system studies.
Goals, Objectives, and Methods: Chelan PUD used radiotelemetry, PIT-tag, and acoustic technologies along with video recordings of bypassed fish to monitor the number, behavior and movement of downstream juvenile salmonids smolts as they were guided by surface collector 1 and 2, and the gatewell collection system. The objective of the study was to evaluate the biological and hydraulic conditions of the fish bypass system. In this evaluation, a second surface collector (SC2) was installed upstream of units 2 and 3, and diversion screens together with a second weir-pipe system in unit 2. In these studies the second surface collector entrance was evaluated with an articulating wall to allow us to evaluate two entrance configurations while surface collector one remained unchanged. The goal was to further increase the fish passage efficiency of the fish bypass system while decreasing any associated descaling and injury.
Key Findings: Results from radio-tagged fish showed that the overall guidance efficiency of the fish bypass system was 23% for yearling Chinook, 49% for steelhead, 9% for sockeye, and 26% for subyearling Chinook through the entire fish bypass system. Preliminary results from the acoustic tag evaluation indicated that 51% of acoustic tagged Chinook smolts and 63% of acoustic tagged steelhead

smolts passed through surface collectors 1 and 2 combined. The PIT tag study indicated that about 51% of the yearling Chinook, 40% of the subyearling Chinook, 61% of the steelhead, and 29% of the sockeye tested used the fish bypass system.

4. Mosey, T.R., K.G. Murdoch, and B.M. Bickford. 1999. Biological and Hydraulic Evaluation of the Rocky Reach Surface Collector 1998. Final Report. Chelan County PUD No. 1, Wenatchee, WA.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Evaluation of Rocky Reach bypass system studies.
Goals, Objectives, and Methods: Chelan PUD used PIT-tag technology and video recorders to monitor the number of downstream juvenile salmonids smolts that were guided by surface collector 1 and 2, and the gatewell collection system. The objective of the study was to evaluate the biological and hydraulic conditions of the fish bypass system. In this evaluation, a second surface collector (SC2) was installed upstream of units 2 and 3, and diversion screens together with a second weir-pipe system in unit 2.
Key Findings: Radiotelemetry showed that more radio-tagged Chinook and steelhead were detected closer to surface collector in the southern portion of the cul-de-sac. Many of the radio-tagged fish initially detected away from the surface collector were later detected near or within a surface collector. An increase in retention efficiency was evident for SC1 where 68%, 82%, and 91% of the sockeye that entered the collector were bypassed to the tailrace of the project.
Hydroacoustic monitoring indicated relatively low densities of fish in front of SC2 compared to fish densities observed in front of the entrance to SC1. Movement upstream of SC1 indicated a directed movement toward the SC1 entrance. Fish trajectories in front of the SC2 entrance also indicated a directed downstream movement but towards the entrance of SC1.
The PIT tag data showed about 27% of the tagged steelhead and yearling Chinook used SC1 and 20% use SC2 and/or the gatewell collection system in units 1 and 2. The combined collection efficiency of the bypass system was over 47% for Chinook and steelhead. The combined collection efficiency for subyearling Chinook was 33% with about 19% that used SC1 and 14% that used SC2 or the gatewell collection system.

5. Mosey, T.R., K. G. Murdoch, and B. M. Bickford. 2001. Biological and Hydraulic Evaluation of the Rocky Reach Surface Collector 2000. Final Report. Chelan County PUD No. 1, Wenatchee, WA.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Evaluation of Rocky Reach bypass system studies.
Goals, Objectives, and Methods: Chelan PUD used radiotelemetry, PIT-tag, and acoustic technologies along with video recordings of bypassed fish to monitor the number, behavior and movement of downstream juvenile salmonids smolts as they were guided by the fish bypass system. Collectively the fish bypass system is surface collector 1 and 2, and the gatewell collection system. The objective of the study was to evaluate the biological and hydraulic conditions of the fish bypass system. In this evaluation, there were no major structural changes to the bypass system from evaluations that occurred in 1999. However, in 1999 the wide versus narrow entrance configuration was tested at SC2. In 2000, the narrow versus midway entrance configuration was evaluated. The goal was to further increase the fish passage efficiency of the fish bypass system while decreasing any associated descaling and injury.
Key Findings: Results from radio-tagged fish showed that the overall guidance efficiency of the fish bypass system was 28% for yearling Chinook, 57% for steelhead, 6% for sockeye through the entire fish bypass system. Results from the acoustic tag evaluation indicated that 48% of acoustic tagged yearling Chinook passed through the powerhouse, 38% through the fish bypass system, and 14% through the spillway. For acoustic tagged steelhead 40% passed the powerhouse, 50% passed through the fish bypass system, and 10% through the spillway. The PIT tag study indicated that about 39% of the yearling Chinook, 27% of the subyearling Chinook, 52% of the steelhead, and 7% of the sockeye were guided by the fish bypass system.

6. Murphy, L.J. and T.R. Mosey. 2002. Biological and Hydraulic Evaluations of the Rocky Reach Fish Bypass System 2001. Final Report. Chelan County PUD No. 1, Wenatchee, WA.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Evaluations at Rocky Reach bypass system studies.
Goals, Objectives, and Methods: PIT-tag, radiotelemetry, hydroacoustic, and video investigations were used to assess the number and behavior of downstream juvenile salmonids smolts that were guided by surface collector 1 and 2, and the gatewell collection system. The objective of the study was to evaluate the biological and hydraulic conditions of the fish bypass system. In this evaluation, surface collector 2 was evaluated with the narrow opening configuration for the duration of the 2001 migration season. The goal was to further increase the fish passage efficiency of the fish bypass system.
Key Findings: Hydroacoustic monitoring indicated relatively low densities of fish in front of SC2 compared to densities in front of the entrance to SC1 and the net movement observed was directed toward the SC1 entrance. Fish trajectories in front of the SC2 entrance also indicated more directed downstream movement toward the entrance of SC1.
Investigators found that fish passage efficiency varied for the fish bypass system and was 9.2-35.6% for yearling Chinook, 65.4-67.0% for steelhead, 18.0-37.8% for sockeye, 39.2% for coho, and 17.9-18.4% for subyearling Chinook. About 1.4 million fish were guided by the fish bypass system and routine sampling indicated the there were very few juvenile salmonids that experienced scale loss or injury as they traveled through the surface collections systems.

D.1.3 Rock Island Annotated Reference List

D.1.3.1 Rock Island: Biological Evaluation

4. Hays, S. 1984. Determination of the Depth Distribution of Juvenile Salmonids in the Turbine Intakes at Rocky Reach and Rock Island Dams. Chelan County Public Utility District, Wenatchee, WA.

Organization: Chelan County PUD
Project: Rock Island and Rocky Reach dam
Type of Evaluation: Assessment of the depth distribution of juvenile salmonids at turbine intakes.
Goals, Objectives, and Methods: The main objective of the study was to determine the depth distribution of juvenile salmonids entering the turbine intakes at both projects. This study was necessary prior to development of a design for a prototype traveling screen deflector for testing at Rock Island and Rocky Reach dams. The District used fyke nets placed within the turbine intakes to determine the depth distribution of migrant salmonids.
Key Findings: The research showed that most juvenile salmonids pass through the upper 50-60% of the turbine intakes at both projects. All species exhibited diel patterns with more fish passing in the upper part of the intake during daylight than in darkness. Sockeye had the most distinct diel pattern with respect to depth during day and night. At Rocky Reach Dam yearling Chinook and coho were distributed higher in the intake than the other fish. At Rock Island Dam steelhead and coho were the species passing nearest the ceiling of the turbine intake.

7. Iverson, T.K., J. Keister, and T.W. Steig. 1996. Hydroacoustic Evaluation of Three Surface Flow Spill Gate Designs and Overall Fish Passage at Rock Island Dam in 1996. Final Report. Hydroacoustic Technology, Inc., Seattle, Washington.

Organization: Chelan County PUD
Project: Rock Island Dam
Type of Evaluation: Hydroacoustic assessment of fish passage with different surface spill configurations.
Goals, Objectives, and Methods: The objective of the study was to evaluate fish passage efficiency for

two spill gate designs: a wide, shallow, overflow spill gate was compared with a narrow, deep-notched spill gate. They also evaluated an overflow weir spill gate design. The investigators used hydroacoustic technology to monitor fish movement at the location of the test spill gates.
Key Findings: The research showed that the notched gates passed significantly more fish per unit flow than overflow gates during both the spring and summer spill studies. In the spring study, notched gates passed 51.3 ± 4.68 fish per kcfs of water spilled while overflow gates passed 36.1 ± 3.57 fish/kcfs. During the summer, notched gates passed 54.0 ± 37.94 fish/kcfs while overflow gates passed 38.6 ± 26.89 fish/kcfs.

Researchers also found that the distribution of smolt passage was strongly influenced by flow patterns and that the center spill gates have a large influence on flow patterns in the forebay of Rock Island Dam. The research indicated that maximum effectiveness of any particular test gate depended on center spill level. In the spring, the level of center spill did not interact with gate location. Instead, during the spring study average number of fish passed per unit flow increased with increasing hours of center spill. In summer, gate effectiveness was affected by the center spill level and also depended on gate location. Fish passage increased with increased hours of center spill at spill bays 16, 24, and 26, but decreased with center spill at spill bays 30 and 32.

17. Skalski, J.R., A.E. Giorgi, J. Lady, J.R. Stevenson, R. Townsend, and K. English. 2000. A Study to Estimate Route-Specific Survival and Passage Probabilities of Chinook Salmon and Steelhead Smolts at Rock Island Dam, 2000. Public Utility District No. 1 of Chelan County, Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Island Dam
Type of Evaluation: Acoustic tag evaluation of route specific survival at the dam.
Goals, Objectives, and Methods: The study reanalyzed data collected at Rock Island Dam to estimate route specific passage and survival.
Key Findings: Passage rates of hatchery yearling Chinook at Rock Island Dam were 24% through the spillway, 7.4% at Powerhouse 1, and 68.1% through Powerhouse 2. Their respective survival through these passage routes was 1.015 (*SE*=0.0217), 0.9115 (*SE*=0.0711), and 0.9722 (*SE*=0.0237). Passage rates for run-of-river Chinook were 24.2% through the spillway, 8.7% at Powerhouse 1, and 67.1% through Powerhouse 2. Their respective survival through these passage routes was 0.9863 (*SE*=0.0305), 0.9702 (*SE*=0.0520), and 0.9959 (*SE*=0.0212). For run-of-river steelhead passage rates were 30.5% through the spillway, 5.7% at Powerhouse 1, and 63.8% through Powerhouse 2. Survival through these passage routes was 0.9668 (*SE*=0.0239), 1.000 (*SE*=0.0493), and 0.9420 (*SE*=0.0227), respectively. There was no statistical difference (P>0.05) between passage and survival probabilities estimated for hatchery and run-of-river Chinook.

18. Steig, T.W. 2001. Review of Acoustic Tag Study Results at Rocky Reach and Rock Island Dams From 1998 Through 2001. Report Prepared for Chelan County PUD No. 1 Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Chelan County PUD
Project: Rocky Reach and Rock Island dams
Type of Evaluation: Brief review of behavior of the behavior exhibited at the District's projects.
Goals, Objectives, and Methods: The review provides a brief summary of the findings from acoustic tag studies that occurred over a 4-year period. The investigators tagged juvenile Chinook and steelhead to determine the movements and behavior near the projects.

Key Findings: The studies at Rocky Reach Dam showed that Chinook and steelhead exhibited various swimming behaviors (milling and straight path) near different passage routes (spill, surface collector, and powerhouse). The horizontal passage distribution across the project was summarized for Chinook (spillway 14%, turbine units 47.6%, and surface collectors 38.4%) and steelhead (spillway 9.8%, turbine units 49.7%, and surface collectors 40.5%). At Rock Island Dam the study was more of a pilot or feasibility study that showed favorable detection rates at the project (range 74-100% per release group) and a total detection rate 89.5%. The study also demonstrated that a majority of the Chinook tagged passed on the Powerhouse No. 2 side (82.3%) of the dam compared to the Powerhouse 1 side (17.7%). The study also demonstrated that the average residence time from release to passing the dam was 91.9 hours (3.8 days) and tag tests showed that average acoustic tag life was 18.2 days.

20. Steig, T.W., J.W. Horchik, and G.W. Tritt. 2002. Monitoring Juvenile Chinook Salmon Migration Routes With Acoustic Tags in the Forebay of Rock Island Dam During 2001. Final Report. Chelan County Public Utility District No. 1, Wenatchee, WA.

Organization: Chelan County PUD
Project: Rock Island Dam
Type of Evaluation: Acoustic tag evaluation of fish movement and passage behavior.
Goals, Objectives, and Methods: The objectives of the study were to monitor the migration routes of juvenile Chinook during their passage through the forebay, their passage location, and to test the feasibility of using acoustic tags to estimate survival through the reservoir and at the dam. Fish were implanted with acoustic tags and released in the tailrace of Rocky Reach Dam. Their movements were monitored in the forebay of Rock Island Dam and further downstream at Crescent Bar.
Key Findings: The research showed that 86% of the Chinook passed on the Powerhouse No. 2 side of the dam while 14% passed on the Powerhouse No. 1 side. The proportion of fish passing through the powerhouses combined was 57% compared to 43% passing through the spillway. Eighty percent of the daily average river flow passed through the powerhouses compared to only 20% of the river flow that passed through the spillway. Passage at the project was strongly correlated (r^2=0.73) with turbine and spill operations. Approximately 80% of the tagged Chinook passed the project during the 12 hours of nighttime. Chinook smolts typically displayed milling behavior prior to passing into both the Powerhouse No.1 turbine units and spill gates. In contrast, the majority of Chinook smolts passing the Powerhouse No. 2 turbine units and spill gates exhibited straight path swimming behavior. The study indicated that it was feasible to use acoustic tagged fish to estimate project and dam survival.

21. Steig, T.W., P. A. Nealson, K. K. Kumagai, L. S. Brown, G.W. Tritt, K.C. Molitor, J. W. Horchik, M.A. Timko, J.C. Sweet, and C. P. Mott. 2006. Route Specific Passage of Juvenile Steelhead, Chinook, and Sockeye Salmon Using Acoustic Tag Methodologies at Rocky Reach and Rock Island Dams in 2005. Report Prepared for Chelan County PUD No. 1, Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Chelan County PUD
Project: Rocky Reach Dam and Rock Island Dam
Type of Evaluation: Acoustic evaluation of route specific fish passage at Rocky Reach Dam.
Goals, Objectives, and Methods: Acoustic tagged steelhead, yearling Chinook, and sockeye were released in several replicates to evaluate fish passage behavior at the dam. The objective of the study was to estimate route specific passage (RSP) at the project in order to evaluate the success of current measures to increase fish survival. As part of the evaluation, investigators compared RSP during spill and non-spill periods.

Key Findings: Route specific passage through the surface collector for steelhead, yearling Chinook, and sockeye was 68%, 32%, and 31%, respectively. Compared to the surface collector, fish passage through turbine units (3-11) was lower for steelhead (18%) and yearling Chinook (19%) but not for sockeye (43%). Fish passage at the spillway was the lowest for all species (2% steelhead, 3% yearling Chinook, and 2% sockeye). Turbine units 1-2 passed 6%, 14%, and 8% for steelhead, yearling Chinook, and sockeye, respectively. When testing spill versus non-spill periods, steelhead and yearling Chinook showed higher surface collector passage rates during spill than during non-spill periods.

Passage rates at units 1-2 decreased for steelhead and Chinook during spill periods and for all tagged species through units 3-11 during spill periods compared to non-spill periods.
At Rock Island Dam, fish passage efficiency was highest for yearling Chinook (0.362), followed by sockeye (0.290), hatchery steelhead (0.219), and run-of-river steelhead (0.201). The majority of run-of-river steelhead passed via Powerhouse 2 (79%), followed by spillway 2 (19%), and relatively few through powerhouse 1 and spillway 1 (1% each). The passage of hatchery steelhead at powerhouse 2 (77%), spillway 2 (20%), powerhouse 1 (1.5%), and spillway 1 (2%) was similar to run-of-river steelhead. The majority of yearling Chinook smolts also passed via powerhouse 2 (60%), a lesser percentage via spillway 2 (34%), and relatively small numbers through powerhouse 1 (3%) and spillway 1 (2%). Sockeye passed Rock Island Dam mostly through powerhouse 2 (70%) and spillway 2 (28%) and few passed powerhouse 1 (1%), and spillway 1(1%).

22. Steig, T.W., P.A. Nealson, K.K. Kumegai, J.W. Horchik, C.P. Mott, and J.C. Sweet. 2006. Route Specific Passage of Juvenile Chinook, Steelhead, and Sockeye Salmon Using Acoustic Tag Methodologies at Rocky Reach and Rock Island Dams in 2004. Report Prepared for Chelan County PUD No. 1, Wenatchee, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Chelan County PUD
Project: Rocky Reach and Rock Island dams
Type of Evaluation: Acoustic evaluation of route specific fish passage.
Goals, Objectives, and Methods: Acoustic tagged steelhead, yearling Chinook, subyearling Chinook, and sockeye were released in several replicates to evaluate fish passage behavior at the dam. The objective of the study was to estimate route specific passage (RSP) at their projects in order to evaluate the success of current measures to increase fish survival. As part of the evaluation, investigators compared RSP during spill and non-spill periods.
Key Findings: Passage at Rocky Reach Dam via the surface collector for yearling and subyearling Chinook, steelhead and sockeye was 27%, 25%, 67%, and 38%, respectively. Chinook smolts passed through Units 3-11 (29%) followed by unguided Units 1-2 (27%), spillway (12%), and the bypass screens at Units1-2 (6%). Sub-yearling Chinook passed through via Units 3-11 (32%), followed by unguided Units 1-2 (27%), spillway (9%), and bypass screens in Units 1-2 (6%). For steelhead, passage was 13% at Units 3-11, 11% unguided Units 1-2, 5% the spillway, and 4% Units 1-2 bypass screens. For sockeye 38% passed Units 3-11 followed by unguided Units 1-2 (12%), and spillway (11%), and bypass screens at Units 1-2 (1%). During spill and non-spill conditions, steelhead passage at the surface collector was 66% and 69%, respectively. During non-spill 26% of yearling Chinook passed the surface collector compared to 27% during spill periods.
At Rock Island Dam the passage distribution for yearling Chinook was primarily through powerhouse 2 (57%), spillway 2 (37%), powerhouse 1 (4%), and spillway 1 (2%). The majority of steelhead passed via Powerhouse 2 (82%) followed by spillway 2 (17%), powerhouse 1 (2%), and spillway 1 (0.1%). Sockeye passed in highest proportion at spillway 2 (45%), followed by powerhouse 2 (30%), powerhouse 1 (15%) and spillway (1%). Sub-yearling Chinook estimates indicated that powerhouse 2 passed 33% and powerhouse 1 passed 29% of the species group in 2004. Spillways 2 and 1 passed smaller proportions by route, 24% and 14% respectively. Seasonal FPE at Rock Island Dam was greater for sockeye (0.550) than for yearling Chinook (0.386), sub-yearling Chinook (0.376), and steelhead (0.167) indicating higher rates of bypass via the spillway.

23. Stevenson, J.R., A.E. Giorgi, W.R Koski, K.K English, and C.A. Grant. 1997. Evaluation of Juvenile Spring Chinook and Steelhead Migratory Patterns at Rocky Reach and Rock Island Dams Using Radio Telemetry Techniques, 1996. Report Prepared for Chelan County PUD No. 1 Wenatchee, Washington. BioAnalysts, Inc., Redmond, Washington.

Organization: Chelan County PUD
Project: Rocky Reach and Rock Island dams
Type of Evaluation: Radiotelemetry evaluation of passage behavior and prototype surface collector

Goals, Objectives, and Methods: The investigators used radiotelementry to monitor the passage of juvenile spring Chinook and steelhead. At Rocky Reach Dam the objective of the research was directed at evaluating the performance of the surface collector and smolt behavior associated with different entrance configurations. At Rock Island Dam the objectives of the research were directed at evaluating the passage of smolts at the project.
Key Findings: Passage at the Rocky Reach Dam for steelhead was 23%, 38%, 8%, and 31% for the spillway, powerhouse, gatewell collection system, and surface collector. At those locations, Chinook passed in the following proportions, 33%, 60% 3%, and 4%, respectively. For steelhead, the wide surface collector entrance configuration (entrance velocity of 2.8 fps and a volume of 1,900 cfs) was more attractive than the narrow configuration (entrance velocity 5.4 fps and volume of 1,100 cfs). The surface collector retained about 42.9% to 66.8% of the steelhead that entered the surface collector under the wide configuration. Based on season wide estimates there were less Chinook that encountered (10.8%) but the surface collector retained more Chinook (88.9%) once they had entered. The surface collector entrance location was favorable to steelhead than Chinook. Most Chinook passed at locations upstream from the surface collector compared to steelhead. Spill was more effective at passing Chinook than steelhead with spill efficiency estimated at 0.98 and 0.69, respectively. In addition, fish guidance efficiency through the gatewell collection system (units 1 and 2), which is close to the surface collector was 33.3% for Chinook and 56.7% for steelhead.
At Rock Island Dam fish passed predominantly through the powerhouses (1& 2) at Rock Island Dam although increased spill tended to increase the proportion of fish through the spillways. Overall, the proportion of steelhead through powerhouse 1 (33%), and powerhouse 2 (29%) was greater than that observed at spillway 1 (19%) and spillway 2 (19%). For Chinook fish passage was greatest through powerhouse 1 (43%) and powerhouse 2 (38%), followed by spillway 2 (12%) and spillway 1 (7%). The percentage of fish passing Rock Island Dam through the spillway was skewed towards increased passage during the high spill periods compared to the low spill periods. During low spill periods, 27 % of the steelhead and 16% of the Chinook passed, but during high spill steelhead increased to 50% and Chinook passage increased to 27%.

24. Stevenson, J.R., J.R. Skalski, P. Westhagen, and A.E. Giorgi. 2004. Fish Passage Efficiency of Juvenile Yearling and Subyearling Chinook, Steelhead and Sockeye at Rocky Reach and Rock Island Dams, 2003: Telemetry Investigation. Chelan County PUD, Wenatchee, Washington.

Organization: Chelan County PUD
Project: Rocky Reach Dam
Type of Evaluation: Evaluation of Rocky Reach fish passage efficiency using radiotelemetry.
Goals, Objectives, and Methods: Radio-tagged yearling Chinook, subyearling Chinook, steelhead, and sockeye were released upstream from the project and were monitored as they passed downstream through the dam. The objective of the study was to identify route of passage for migrant smolts in order to evaluation the performance of fish bypass systems (surface collector, and unit 1 and 2 diversion screens) and spill effectiveness at the project. Fish passage efficiency (FPE) is the proportion of study fish that pass a particular bypass system and fish bypass efficiency (FBE) is the proportion of study fish that pass the surface collector and diversion screens combined. Spill passage efficiency is the proportion of fish passing the project via the spillway relative to the volume of water spilled.
Key Findings: Rocky Reach had low estimates of FPE for sockeye and subyearling Chinook but passage performance through the bypass system was relatively high for steelhead and yearling Chinook. The FPE for yearling Chinook, steelhead, sockeye, and subyearling Chinook was 66%, 68%, 31%, and 42%, respectively. The FBE was 53% for yearling Chinook, 58% for steelhead, 17% for sockeye, and 37% for subyearling Chinook. Spill was an ineffective (< 1.0) method for passing fish at Rocky Reach Dam. Spill efficiencies observed were low for yearling Chinook, steelhead, sockeye, and subyearling Chinook were 0.67, 0.50, 0.58, and 0.33, respectively.
Rock Island had low estimates of FPE for steelhead and subyearling Chinook but passage performance through the bypass system was relatively high for sockeye and yearling Chinook. The FPE for yearling Chinook, steelhead, sockeye, and subyearling Chinook was 47%, 36%, 46%, and 14%, respectively.

Spill was an effective (> 1.0) method for passing all fish except subyearling Chinook at Rock Island Dam. Spill efficiencies exceeded 1.0, for yearling Chinook (2.36), steelhead (1.79), and sockeye (2.28), but were low for subyearling Chinook (0.68).

D.1.3.2 Rock Island: Multidisciplinary

2. District Staff, et. al. 1995. Rocky Reach Dam and Rock Island Dam Fish Bypass Annual Project Team Report for Period Ending December 1994. Summary Report Prepared for Public Utility District No. 1 of Chelan County, Washington.

Organization: Public Utility District No. 1 of Chelan County
Project: Rock Island and Rocky Reach Dams
Type of Evaluation: First annual report from the Rock Island and Rocky Reach juvenile fish bypass project design team.
Goals, Objectives, and Methods: The report summarizes the developments made on the fish bypass designs and planning at both projects during 1993 and 1994. It documented the current project status, communicated proposed courses of action for future progress and the logic applied in adopting these courses, reported progress relative to compliance with the Federal Energy Regulatory Commission Agreements, and provided a vehicle for the parties involved in the project to communicate this information.
Key Findings: The document outlines the basis for development of a surface bypass facility at Rocky Reach Dam.

4. Oakwood Consulting Inc. 2006. Summary of Hydraulic and Fish Passage Characteristics for Top-Spill Bypasses at Rock Island, Wanapum and Priest Rapids Dams. Report Submitted to U.S. Army Corps of Engineers Walla Walla District. Oakwood Consulting Inc, Belcarra, BC, Canada.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Rock Island, Wanapum, and Priest Rapids Dams
Type of Evaluation: Summary of hydraulic and fish passage characteristics
Goals, Objectives, and Methods: The objective of this paper was to summarize the topspill events at the Rock Island, Wanapum, and Priest Rapids Dams. The hydraulic and fish passage characteristics were noted for each dam.
Key Findings: Rock Island Dam: During 1996 it was determined that a narrower and deeper fish passage opening had a larger zone of influence in the forebay and drew flow from deeper depths during a topspill event. In 1997 top spill openings were constructed for fish passage. The optimal opening width was 9 ft, for a fish passage efficiency of 44.8 fish per unit of flow. In 1998 and 1999 the nappe characteristics were evaluated and the measured impact velocity on the flat apron ranged from 50 ft/s to 10 ft/s, dependent upon the tailwater depth, which varied from 5 to 50 ft, respectively. During 2000 and 2001 fish survival studies were completed while using deflectors at the end of the submerged aprons in spillbays 29 and 16. Passage through spillbay 29 was found to be benign to fish. Passage though spillbay 16 resulted in a direct survival based upon pooled data of 0.99 and 1.5% injuries. In 2005 an overflow-underflow gate that attracts fish to the surface flow while minimizing dissolved gas uptake with the bottom flow was tested for fish survival. The 48 hr survival probabilities were 1.0 for the pool aerated condition and 0.991 (for the non-aerated condition.
Wanapum Dam: In 1995 and 1996, a topspill-type bulk head was tested at both model and prototype scale. The amount of turbulence and the water level between the bulkhead and tainter gate were found to be depended on the amount the tainter gate was open. Small gate openings reduced the turbulence, but increased the water level. In addition, strong vorticity was observed between the bulkhead and the tainter gate. At flow of 2000 and 4000 cfs the 48 hr fish survival probability was 0.92 with 6.6% injury and 0.969 with 7.0% injury, respectively. In 2002 the bulkhead was modified to help streamline the approach flow. With this new design the 48 hr survival probability was 0.99 with 0.7% injury. The bulkhead was modified again in 2004 to increase the discharge and change the aspect ratio at the opening. The width

was reduced and the sill elevation lowered. A tracking study showed that of the fish that came within 300 and 50 ft of the bypass 86% and 100% passed though the topspill, respectively.
Priest Rapids: None.

D.1.4 Wanapum Annotated Reference List

D.1.4.1 Wanapum: Engineering Design

6. Weitkamp, D.E. and R.A. Elder. 1994. Recommendations for Fish Bypass Outfall Location, Wanapum Dam. Prepared for Grant County Public Utility District, Kirkland, WA. Parametrix, Inc.

Organization: Public Utility District No. 1 of Grant County
Project: Wanapum Dam
Type of Evaluation: Selection of a fish bypass outfall location.
Goals, Objectives, and Methods: The objective of the study was to locate suitable juvenile bypass outfall sites below the dam. The selection was based upon several assumptions regarding bypassed fish, predators and the outfall structure itself. The selection made use of actual field and 1:100 scale tailrace model flow field observations and velocity measurements.
Key Findings: A small range of suitable outfall locations were identified.

D.1.4.2 Wanapum: Biological Evaluation

6. Kumagai, K.K., B.H. Ransom, and H.A. Sloan. 1996. Effectiveness of a Prototype Surface Flow Attraction Channel for Passing Juvenile Salmon and Steelhead Trout at Wanapum Dam During Summer 1996. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc. Seattle, WA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Evaluation of a prototype Surface Flow Attraction Channel (SFAC).
Goals, Objectives, and Methods: The objective of the study was to determine the SFAC effectiveness in passing juvenile salmonids. In 1995 the prototype SFAC spanned turbine intakes 7A to 10B and had a single vertical slot opening above turbine intake 8B. However, the apparent fish avoidance of the SFAC experienced in 1995 lead to modifications that extended the channel in 8 ft sections to include turbine units 4-6 with a new single horizontal inflow entrance slot relocated above turbine unit 6. The fish collection efficiency (FCE) relative to unit 6 was calculated as the proportion of fish passing through the channel entrance slot divided by the total fish passing the slot and turbine unit 6. Overall FCE was also calculated for all turbine units. Several hydroacoustic transducers were strategically placed to monitor the turbine units and entrance to the SFAC.
Key Findings: The daily FCE (unit 6 only) averaged 23% and ranged from 0-56%. FCE for all turbine units averaged 2% but increased to 3% when turbine units 1-3 were off. Daytime FCE (23%) was lower than night (26%). Relative to the total project fish passage (SFAC + turbines + spillway + sluiceway), FCE (project) was 0.3%.
The overall FCE's for the SFAC have not increased over the past two years (both spring and summer). The SFAC has been tested with different channel configurations (shallow, deep, vertical, and horizontal), channel operations (500-1,400 cfs and 1.0-4.5 fps), channel length, and powerhouse operations. These configurations and operational changes appeared to have had little effect on FCE. While physical factors seem to have little effect on improving FCE, the biological components may be a key to increasing FCE. Higher FCE have occurred later in the spring possibly due to changes in species composition, size of fish, and /or degree of smoltification.

7. Kumagai, K.K., B.H. Ransom, H.A. Sloan, and H. Charvet. 1997. Effectiveness of a Prototype Surface Flow Attraction Channel for Passing Juvenile Salmon and Steelhead Trout at Wanapum Dam During Spring 1997. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology Inc. Seattle, WA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Evaluation of a prototype Surface Flow Attraction Channel (SFAC).
Goals, Objectives, and Methods: The objective of the study was to determine the SFAC effectiveness in passing juvenile salmonids. In 1995 the prototype SFAC spanned turbine intakes 7A to 10B and had a single vertical slot opening above turbine intake 8B. However, the apparent fish avoidance of the SFAC experienced in 1995 lead to modifications that extended the channel in 8 ft sections to include turbine units 4-6 with a new single horizontal inflow entrance slot relocated above turbine unit 6. In 1997 the SFAC spanned units 1-10 with a vertical slot opening above turbine unit 8 was tested from April 21 to May 13. This set up was reconfigured to test an opening above unit 1B that was tested from May 14 to June 13. Fish collection efficiency (FCE) was calculated as the proportion of fish passing through the channel entrance slot divided by the total fish passing the slot and turbine units 1 and 8. Overall FCE was also calculated for all turbine units. Several hydroacoustic transducers were strategically placed to monitor the turbine units and entrance to the SFAC.
Key Findings: The daily FCE (unit 8 only) averaged 23% and ranged from 7-57%. FCE for all turbine units averaged 0.9%. Daytime FCE (20%) was lower than night (27%). The daily FCE (unit 1 only) averaged 0.4% and ranged from 0-4%. FCE for all turbine units averaged 0.1%. Daytime FCE (0.2%) was lower than night (0.6%). The daily FCE relative to the total project fish passage (SFAC + turbines + spillway + sluiceway) was 0.3%. Total project FCE was greater for turbine unit 8 (0.5%) than unit 1 (0.1%).
Regardless of SFAC opening location, most fish passage was concentrated at the north end of the powerhouse, over two-thirds of the fish had passed the powerhouse by turbine unit 3 (68% and 66%, when SFAC opening above turbine intakes 8B and 1B, respectively). The highest passage was at turbine unit 1 (39% and 31%) when the opening was above turbine intakes 8B and 1B, respectively. The lowest fish passage (3%) occurred at turbine unit 8 when the opening was located at that unit. The lowest fish passage when the opening was at unit 1 occurred at unit 9.
While the FCEs relative to a single turbine unit were lower than the previous 2 years, the powerhouse fish passage was concentrated between turbine units 1 and 2, accomplishing an important criterion for effective bypass systems (i.e. concentrating fish in the horizontal dimension). A second criterion, providing a passage route in the upper water column, was not accomplished in 1997.

9. Nealson, P.A., R.L. Evenson, and K.K. Kumagai. 1997. Fish Distributions and Trajectories in The Wanapum Dam Forebay During 1996. Prepared for Grant County Public Utility District. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Evaluation of fish condition and survival through selected passage routes at Wanapum Dam.
Goals, Objectives, and Methods: The objective was to estimate the distribution and relative densities of fish approaching the dam. Investigators used fixed and mobile survey hydroacoustic techniques to monitor fish in the forebay of Wanapum Dam.
Key Findings: The highest areas of mean fish density were observed about 3,000 ft upstream from the dam on the east side of the river, and in the area about 100-300 ft upstream of the powerhouse, primarily in front of units 6-9. These areas correspond to drop off along the natural river channel. The proportion of fish observed during the day (31%) was less than night (69%), and fish were more evenly dispersed at night.
Distinct trends with respect to mean direction of movement were not observed between the day and night survey periods. At night, evidence of downstream passage toward the spillway was noted in the area immediately in front of the surface flow attraction channel (SFAC). Mean nighttime fish movement in front of the powerhouse was generally downstream and away from the dam at Units 1-3, and downstream, toward the spillway at Units 8 and 10. During the day surveys along the face of the powerhouse, fish were observed only in front of Units 6-8. For day surveys, mean observed fish movement was upstream

and away from the dam at Units 6-7 and toward the powerhouse and SFAC at Unit 8.
Mean fish vertical distribution was deepest furthest away from the project becoming shallower toward the dam (about 33 ft.) until fish were in front of the SFAC where fish increased their depth to 52 ft. Mean trajectory profiles were similar between spring and summer. Below a depth of 40 ft, about the top of the intake opening, fish approaching the dam exhibited consistent diving behavior at Units 6 and 8 where the entrance to the SFAC had been located.

10. Normandeau Associates and J.R. Skalski. 2002. Evaluation of Smolt Mortality and Injury Associated With Passage Through A Modified Top Spill Bulkhead Spillway at Wanapum Dam, Columbia River. Report Prepared for Grant County PUD No. 2, Ephrata, Washington. Normandeau Associates, Inc. Drumore, PA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Radiotelemetry evaluation of survival through a modified top spill spillbay.
Goals, Objectives, and Methods: The objective of the study was to estimate the survival (48 h) of hatchery-reared Chinook salmon through a modified overflow weir installed in spillbay 12 at spill rate of 10,000 cfs). The investigators used radio-tagged fish to assess survival.
Key Findings: Survival estimated through the modified spillbay was 0.990. The survival through the new overflow weir with its different design and tainter gate operation was higher than the one tested in 1996 (survival 0.920 at 2,000 cfs and survival at 0.969 at 4,000cfs). The injury rate was low at 0.7% for top spilled fish, which is lower than the rate of 5.4% and 5.8% experienced in 1996 for the 2,000 and 4,000 cfs conditions.

11. Normandeau Associates, Inc., Parametrix, Inc., and J.R. Skalski. 1996. Behavior of Juvenile Salmonids Relative to the Prototype Surface Bypass Collection Channel at Wanapum Dam, Columbia River, Washington. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Normandeau Associates, Inc., Drumore, PA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Radiotelemetry evaluation of a prototype Surface Flow Attraction Channel (SFAC) along with movement and behavior near the Projects.

Goals, Objectives, and Methods: The objective of the study was to assess the movement and behavior of in-river spring Chinook and steelhead approaching Wanapum Dam and in the vicinity of the prototype surface fish attraction channel (SFAC) and other passage routes were determined. Investigators used radio-tagged fish to assess the movement and behavior of smolts near the project.
Key Findings: High proportions of both Chinook (0.70) and steelhead (0.73) were initially detected at the upstream end of the powerhouse, which indicated that smolts approached the project along the left bank following the natural river channel. Detection time and average detection time per fish indicated that both species tended to spend more time adjacent to Units 6-10 than Units 1-5, despite the relatively high fish detection rate at the lower numbered units. The longest detection time at the powerhouse occurred in the near field of Unit 8 for each species. More fish were detected at either end of the powerhouse (Units 1-3 and 8-10) than at Units 4-7.
Only 14% of the Chinook and 31% of the steelhead monitored upstream from the project were located in the vicinity of the SFAC indicating that a large proportion of smolts were never exposed to the SFAC opening. It appears that the smolts were diverted either through the turbines at the upper end of the powerhouse, sluiceway or spillway. Field observations suggest that low level sounds resonate from the SFAC, which make act as a deterrent causing fish to avoid the area near the SFAC. At the spillway both species tended to spend more time in the mid-spillway area than to either side. The average detection rate at the sluiceway and spillway was about 11% for Chinook and about 30% for steelhead.
The majority of Chinook (52%) and many of the steelhead (25%) passed the project through the turbine

units. In comparison, few (6.5%) Chinook used the spillway in compared to steelhead (26%). About 1% of both species used the SFAC. Fish guidance efficiency (FGE) of the SFAC relative to all fish detected at the project was 0.0081 and 0.0079 for Chinook and steelhead, respectively. At the sluiceway, equipped with the overflow weir, surface bypass was more efficient passing 6% of the Chinook and 33% of the steelhead smolts with less than 2% of the total river flow.

13. Normandeau Associates, Inc., Parametrix, Inc., and J.R. Skalski. 1998. Response of Salmonid Smolts to a Prototype Surface Collector at Wanapum Dam, and Smolt Movement and Behavior at Priest Rapids Dam, Columbia River, Washington. Normandeau Associates, Inc., Drumore, PA.

Organization: Grant County PUD
Project: Wanapum and Priest Rapids dam
Type of Evaluation: Radiotelemetry evaluation of a prototype Surface Flow Attraction Channel (SFAC) along with movement and behavior near the Projects.
Goals, Objectives, and Methods: The objective of the study was to assess the movement and behavior of spring Chinook and steelhead approaching Wanapum Dam and in the vicinity of the prototype surface fish attraction channel (SFAC). Investigators used radio-tagged fish to assess the movement and behavior of smolts near the project.
Key Findings: High proportions of both Chinook (0.64) and steelhead (0.71) were initially detected at the upstream end of the powerhouse, which indicated that smolts approached the project along the left bank following the natural river channel. Low detection rates observed for Chinook (11%) and steelhead (23%) smolts in the vicinity of the SFAC indicate smolts were being diverted either to the units at the upper end of the powerhouse, sluiceway or spillway. The majority of Chinook (60%) and steelhead (68%) passed the project via the spillway. Some 36% and 26% of the Chinook and steelhead respectively, passed through the turbines.
The proportions of each species using the SFAC were nearly equal (about 1%). The extension of the SFAC upstream to unit 1 may have diverted fish away from the powerhouse and increased the proportion passing the spillway. Fish guidance efficiency (FGE) of the SFAC relative to all Chinook detected in the forebay with the SFAC entrance at Unit 8 was 0.0116. The respective FGE values for Chinook and steelhead smolts, which were detected in the forebay prior to passage after the SFAC entrance was moved to Unit 1 were 0.0194 and 0.0098. The low FGE estimates suggest are consistent with 1996 findings and suggest that the SFAC in its current configuration may not be a viable bypass system.
At Priest Rapids dam passage routes utilized by the Chinook and steelhead differed. More steelhead passed the spillway (55%) compared to Chinook where the majority of fish (70%) passed the turbines at Priest Rapids.

16. Ransom, B.H. 1997. Summary of Spillway and Sluiceway Effectiveness in Passing Juvenile Salmonid at Wanapum and Priest Rapids Dams From 1980-1996. Prepared for Grant County Public Utility District. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Synthesis of spillway and sluiceway passage effectiveness studies.
Goals, Objectives, and Methods: The objective of the report was to summarize the finding of spillway and sluiceway effectiveness studies at Priest and Wanapum dams from 1980 through 1996. Spillway (or sluiceway) effectiveness was calculated as the percent of all fish passage at the entire dam that passed through the spillway (or (sluiceway). Spillway (or sluiceway) efficiency was calculated as the ratio of the percent of fish passed in spill (or sluiceway), divided by the percent of total river flow passed as spill (or sluiceway).
Key Findings: Over the years of study at both projects the trend has been that sluiceway efficiency has been consistently higher than spillway, more so during spring and summer. Also daytime spillway efficiency was consistently greater than during nighttime (although nighttime fish passage rates generally exceeded daytime rates).

17. Ransom, B.H., B.D. McFadden, and B.A. Schnebly. 1991. Hydroacoustic Evaluation of the Effectiveness of the Sluiceway at Wanapum Dam in Passing Juvenile Salmon and Steelhead Trout During Spring 1991. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Evaluation of fish passage through Wanapum Dam.
Goals, Objectives, and Methods: The objective of the study was to assess the effectiveness of the dam's sluiceway in passing downstream migrating juvenile salmonids and the distribution of fish passage at the project. Hydroacoustic techniques were used to monitor fish near the spillway by mounting surface and bottom transducers aimed to monitor fish in the water column in front of the spillbay. At the sluiceway, transducers were mounted underneath the sluiceway opening.
Key Findings: The sluiceway was found to provide a relatively effective means of passing downstream migrants. Sluiceway effectiveness at passing migrant salmonids was higher during the day (6 % of total dam passage) than during the night (4 % of total dam passage). During the day the sluiceway passed 6% of the fish and 1.5% of the total water passing the dam. Combined daily (24 h) average passage at the sluiceway was 3 % of the total fish and 1.2 % of the total water at the dam. At night the spillway passed 35% of the fish and 31.7% of the water at the dam. In the day the spillway passed 20% of the fish and 17.4% of the water at the dam. Researchers believe that reduced sluiceway effectiveness from previous years (1989 and 1990) may have been related to powerhouse operation. Water passing the powerhouse in this study passed through turbine units farther from the sluiceway than during the previous studies. During 1989 and 1990, the surface flow of the sluiceway was on average 5.3 times more effective at passing fish than the deep flow of the spillway. In this study, the sluiceway was about 2.5 times more efficient at passing fish than the spillway.

18. Ransom, B.H., K.K. Kumagai, A.G. Birmingham, K.A. Divens, and P.A. Nealson. 1996. Effectiveness of a Prototype Surface Flow Attraction Channel for Passing Juvenile Salmon and Steelhead Trout at Wanapum Dam During Spring and Summer 1995. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Hydroacoustic evaluation of a prototype Surface Flow Attraction Channel (SFAC).
Goals, Objectives, and Methods: The objective of the study was to determine the effectiveness of the SFAC in passing juvenile salmonids at Wanapum Dam. Effectiveness was estimated by the fish collection efficiency (FCE) that was calculated as the proportion of the fish passing through the channel entrance slot divided by the total fish passing through the slot and turbine unit 8. Hydroacoustic transducers were strategically placed to monitor the fish movement and behavior at the SFAC.
Key Findings: The SFAC was tested on several conditions: Condition 1-16 X 50 ft slot opening, 1,400 cfs flow, 2.0 fps velocity; Condition 2-16 X 20 ft, 1,400 cfs flow, 4.5 fps velocity; Condition 3-16 X 20 ft, 800 cfs flow, 2.5 fps velocity; Condition 4-16 X 50 ft, 500 cfs flow, 1.0 fps velocity. Regardless of test condition, FCE was statistically higher during the second half of the spring outmigration. FCE prior to May 18 averaged 18% (n=18), while FCE after May 17 averaged 41% (n=18). Daily FCE (re TU 8) varied for the SFAC and ranged from 9% to 54%. FCE tests during the spring (36 daily FCE tests) averaged 30% and FCE (re TU 7-9) averaged 12%. Researcher noted that after May 17 the typical nighttime SFAC fish passage shifted to predominantly daytime passage (sluiceway diel passage also shifted toward daytime hours). Vertical distribution observed also confirms a shift 7 ft higher in the water column after May 17. The higher spring FCE after mid-May suggested that smoltification may have played a key role in the success of the SFAC. Fish trajectories generally followed flow lines and when in front of the SFAC slot fish exhibited a consistent diving trajectory for all operating conditions. The horizontal distribution for the entire powerhouse during the days when the channel was in operation showed that fish passage was strongly weighted toward the lower numbered units. Turbine units 1-6

passed 92% and turbine units 7-9 passed 8% of the powerhouse fish in 39% of the powerhouse flow. Sluiceway effectiveness relative to total project passage averaged 12% during SFAC operation, higher than the mean of 5% observed for spring 1989-1991. Spillway effectiveness averaged 42% compared to the mean of 31% for the 10 previous years. The relatively high sluiceway and spillway effectiveness may have been the result of the SFAC deflecting fish away to those locations resulting in higher than normal passage at those locations.

19. Ransom, B.H., K.K. Kumagai, B.A. Schnebly, and A.G. Birmingham. 1998. Hydroacoustic Evaluation of Prototype in-Turbine Diversion Screens for Subyearling Chinook Salmon at Wanapum Dam During Summer 1994. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Evaluation of prototype diversion screens at the turbine intakes at Wanapum Dam.
Goals, Objectives, and Methods: Investigators used hydroacoustic techniques to monitor fish passage at the intakes of turbine unit 4 where the diversion screen was installed. Transducers were installed in-turbine at the bottom of the downstream side of the trash rack and monitored the area immediately upstream of the prototype In-Turbine Diversion Screen (IDS). The prototype IDS was a fixed screen composed of bar mesh screen with the bars running parallel to the intake water flow lines. The IDS was 24 ft. long and set at a fixed angle of 50° up from vertical. A 4 ft extension was added to the upstream end of the screen and was oriented from the rest of the screen by an additional 20°. The objective of the assessments was to characterize juvenile salmonids passage during IDS operation.
Key Findings: Baseline fish passage parameters were evaluated during 1989 at Wanapum Dam, and an initial study of the IDS was conducted during 1990. Further evaluations were conducted to refine the effectiveness of the IDS from 1991 to 1993. During 1994, prototype IDS's were also installed for the first time in turbine intakes 4A and 4C. Three conditions were tested in 1994: 1) IDS-out (baseline condition), 2) IDS-In (experimental condition), and 3) FGE test condition with both IDS in and fyke nets in place. Fish velocities were slower at the leading edge of the IDS during IDS-In conditions indicating that fish may have been fighting the flow and the trajectories indicated that fish may have been diving under the IDS. Fish were consistently higher in the water column during the IDS-out condition than with the IDS-in condition. Fish passage was lowest in intake 4B for the IDS-out and IDS-in conditions. The distribution of fish also dropped in the center intake (4B) with the IDS-in condition.

20. Ransom, B.H. and K.M. Malone. 1990. Hydroacoustic Evaluation of the Effectiveness of the Sluiceway at Wanapum Dam in Passing Juvenile Salmon and Steelhead Trout During Spring 1990, Draft. Report Prepared for Grant County PUD No. 2, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Evaluation of fish passage through Wanapum Dam.
Goals, Objectives, and Methods: The objective of the study was to assess the effectiveness of the dam's sluiceway in passing downstream migrating juvenile salmonids and the distribution of fish passage at the project. Hydroacoustic techniques were used to monitor fish near the spillway by mounting surface and bottom transducers aimed to monitor fish in the water column in front of the spillbay. At the sluiceway, transducers were mounted underneath the sluiceway opening.
Key Findings: The sluiceway was found to provide a relatively effective means of passing downstream migrants. Sluiceway effectiveness at passing migrant salmonids was higher during the daylight than during hours of darkness. During the hours that the sluiceway was operated (2000-0600 h) the sluiceway passed 6% of the fish and 1.4% of the total water passing the dam. Combined daily (24 h) average passage at the sluiceway was 4 % of the total fish and 0.5% of the total water at the dam. During the hours of operation (1800-0600 h) the spillway passed 24% of the fish and 29% of the water at the dam.

On a daily (24 h) average the spillway passed 18% of the fish and 22% of the water at the dam. Reduced sluiceway and spillway effectiveness may have been a function of higher than normal river flows, high levels of spill, and the fact that some turbine units were not operating.

25. Skalski, J.R., Normandeau Associates, and Mid-Columbia Consulting. 1996. Fish Survival in Passage Through the Spillway and Sluiceway at Wanapum Dam on the Columbia River, Washington. Report Prepared for Grant County PUD No. 2, Ephrata, Washington. Columbia Basin Research, School of Fisheries, University of Washington, Seattle, Washington.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Evaluation of fish condition and survival through selected passage routes at Wanapum Dam.
Goals, Objectives, and Methods: Investigators used balloon and radio tags to monitor the movements and facilitate recapture of juvenile Chinook salmon. The objectives were to estimate immediate (1 h) and 48 h survival probabilities of Chinook smolts in passage through spillbays equipped with a flow deflector, without a flow deflector, an overflow weir and the ice/trash sluice. The researcher also included identification of the nature, magnitude, and probable source of injuries to experimental fish.
Key Findings: The 48 h survival probability through different passage routes at Wanapum Dam were from highest to lowest 99.6% at spillbay 3 (unmodified), 95.7% at spillbay 2 (with flow deflector), 97.4% at the sluiceway at 2,000 cfs, and 92.0% at the overflow weir at 2,000 cfs. Increasing spill volume increased survival through the overflow weir but the increase was not significant (P>0.05). The fish injury rates varied along the spill routes and shoed some contrasting trends to that observed for the estimated survival probabilities. Relative to controls, fish injury rates at spillbay 3 (5.4%) and the overflow weir, 5.4%-5.8% (both discharges) were higher than for those at spillbay 2 (3%) and the sluiceway (1.4%). Injuries inflicted at spillbay 2 and overflow weir proved lethal (48 h) to a greater proportion of fish than at the sluiceway and spillbay 3. The probable source of injuries among the spillbay and sluiceway fish was mechanical (up to 3.4%) while 2.0% to 3.2% of the overflow weir fish provided evidence of pressure-related injuries. A greater proportion (0.035) of fish showed loss of equilibrium in passage through the sluiceway; however, this was not lethal over the 48 h period.

26. Voskuilen, M. 1995. Wanapum Dam Attraction Flow Prototype Design Considerations: A Review of the 1981 to 1992 Hydroacoustic Studies of the Wells Dam Juvenile Fish Bypass System. Report Prepared for Public Utility District No. 2 of Grant County. Sverdrup Corporation.

Organization: Grant County PUD
Project: Wells Dam
Type of Evaluation: Hydroacoustic studies
Goals, Objectives, and Methods: To review the performance of the Wells Dam attraction flow bypass from 1981 to 1992.
Key Findings: There was a local vertical redistribution of fish near the bypass slot flow: the fish were higher in the water column, especially at night. In addition, the FGE was similar when the flow through the slot was driven by under flow below the spillway gates or spill flow over the gates. The FGE was also similar during day and night opening conditions. Furthermore, there was little vertical variation in the day and night forebay distribution. The effectiveness of the slot was not impacted by simultaneously operating the bypass slot and the adjacent turbine. The Wells slot design was impact by the physical characteristics of the dam, and may not represent the optimal configuration at other dams.

D.1.4.5 Wanapum: Multidisciplinary

4. Jacobs Civil Inc., Grant County PUD, Oakwood Consulting Inc., NOAA Fisheries, and IIHR Hydroscience and Engineering. 2004. Design Team Plan for Development of Downstream Fish Passage Measures at Wanapum Dam 2003-2004.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Plan and decision tree.
Goals, Objectives, and Methods: The purpose of this report was to lay out the plan to reach a survival rate of 95% of the juvenile salmonids passing Wanapum Dam.
Key Findings: The design team came up with a detailed task list to advance the Wanapum Dam fish passage concept. These tasks included developing a general design, studying entrance behavior, assessing fish survival at the bypass exit, undertaking CFD and hydraulic scale modeling, selecting the preferred design, assessing the potential for prototyping, advancing the preferred design, testing and evaluating the prototype design, completing and implementing the final design, and field testing the final design. A decision tree was also included.

6. Oakwood Consulting Inc. 2006. Summary of Hydraulic and Fish Passage Characteristics for Top-Spill Bypasses at Rock Island, Wanapum and Priest Rapids Dams. Report Submitted to U.S. Army Corps of Engineers Walla Walla District. Oakwood Consulting Inc, Belcarra, BC, Canada.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Rock Island, Wanapum, and Priest Rapids Dams
Type of Evaluation: Summary of hydraulic and fish passage characteristics
Goals, Objectives, and Methods: The objective of this paper was to summarize the topspill events at the Rock Island, Wanapum, and Priest Rapids Dams. The hydraulic and fish passage characteristics were noted for each dam.
Key Findings: Rock Island Dam: During 1996 it was determined that a narrower and deeper fish passage opening had a larger zone of influence in the forebay and drew flow from deeper depths during a topspill event. In 1997 top spill openings were constructed for fish passage. The optimal opening width was 9 ft, for a fish passage efficiency of 44.8 fish per unit of flow. In 1998 and 1999 the nappe characteristics were evaluated and the measured impact velocity on the flat apron ranged from 50 ft/s to 10 ft/s, dependent upon the tailwater depth, which varied from 5 to 50 ft, respectively. During 2000 and 2001 fish survival studies were completed while using deflectors at the end of the submerged aprons in spillbays 29 and 16. Passage through spillbay 29 was found to be benign to fish. Passage though spillbay 16 resulted in a direct survival based upon pooled data of 0.99 and 1.5% injuries. In 2005 an overflow-underflow gate that attracts fish to the surface flow while minimizing dissolved gas uptake with the bottom flow was tested for fish survival. The 48 hr survival probabilities were 1.0 for the pool aerated condition and 0.991 (for the non-aerated condition.
Wanapum Dam: In 1995 and 1996, a topspill-type bulk head was tested at both model and prototype scale. The amount of turbulence and the water level between the bulkhead and tainter gate were found to be depended on the amount the tainter gate was open. Small gate openings reduced the turbulence, but increased the water level. In addition, strong vorticity was observed between the bulkhead and the tainter gate. At flow of 2000 and 4000 cfs the 48 hr fish survival probability was 0.92 with 6.6% injury and 0.969 with 7.0% injury, respectively. In 2002 the bulkhead was modified to help streamline the approach flow. With this new design the 48 hr survival probability was 0.99 with 0.7% injury. The bulkhead was modified again in 2004 to increase the discharge and change the aspect ratio at the opening. The width was reduced and the sill elevation lowered. A tracking study showed that of the fish that came within 300 and 50 ft of the bypass 86% and 100% pass ed though the topspill, respectively.
Priest Rapids: None.

7. Oakwood Consulting Inc. 2005. Wanapum Dam Future Unit Fish Bypass Hydraulic Design Summary Report. Prepared For Public Utility District No. 2 of Grant County. Oakwood Consulting, Belcarra, BC, CA.

Organization: Grant County PUD
Project: Wanapum Dam
Type of Evaluation: Hydraulic design

Goals, Objectives, and Methods: The purpose of this report was to summarize the hydraulic design of the future unit fish bypass and present the basic hydraulic features. The following models were completed during the bypass development

- 1:50 scale physical model of the forebay, spillway, and powerhouse. The model was used to asses various locations and alternatives for the fish bypass and to develop the bypass entrance.
- 1:52 scale model of the tailrace, spillway, and powerhouse. This model was used to develop a design that would spread bypass flow into the tailrace, study scour patterns, and dissolved gas uptake.
- 1:24 scale model of the bypass. This model was used to study the hydrodynamic characteristics associated with the various bypass alternatives.
- CFD model of the forebay, powerhouse, and spillway. This model was used to evaluate the trajectory of the bypass.
- CFD model of the tailrace powerhouse, and spillway. This model was used to evaluate the trajectory of the bypass.
- CFD model of the bypass structure. This model was used to calculate velocity profiles and cavitation pressures.

Key Findings: The center intake bay of powerhouse Unit 11 was selected as the bypass entrance location. The bay was narrowed and the entrance was designed as a free-surface bypass. Measured were included at the bypass entrance to minimize vorticity and eliminate flow separation. Field studies showed that smolt would accept the bypass opening. Model studies showed that there would be competition for flow between the bypass and powerhouse Unit 10 at depth of greater than 50 ft. Test data showed that the bypass exit design had 100% smolt survival and less than 1% injured. The gate settings, hydraulic capacity, water surface profiles, crest pressures, bypass flow velocities, cavitation, air, and tailrace conditions were also discussed in this report.

D.1.5 Priest Rapids Annotated Reference List

D.1.5.1 Priest Rapids: Engineering Design

2. Weitkamp, D.E. and D. Hay. 1996. Recommendations for Fish Bypass Outfall Location, Priest Rapids Dam. Parametrix, Inc. and Hay & Company for Grant County Public Utility District, Kirkland, WA.

Organization: Public Utility District No. 1 of Grant County
Project: Priest Rapids Dam
Type of Evaluation: Selection of a fish bypass outfall location.
Goals, Objectives, and Methods: The objective of the study was to locate suitable juvenile bypass outfall sites below the dam. The selection was based upon several assumptions regarding bypassed fish, predators and the outfall structure itself. The selection made use of actual field and 1:100 scale tailrace model flow field observations and velocity measurements.
Key Findings: A small range of suitable outfall locations were identified.

D.1.5.2 Priest Rapids: Biological Evaluation

3. McFadden, B.D., B.H. Ransom, and B.A. Schnebly. 1993. Hydroacoustic Evaluation of the Effectiveness of the Sluiceway at Priest Rapids Dam in Passing Juvenile Salmon and Steelhead Trout During Spring and Summer 1992. Report Prepared for Grant County Public Utility District, Ephrata, WA. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Grant County PUD
Project: Priest Rapids Dam
Type of Evaluation: Evaluation of sluiceway fish passage at Priest Rapids Dam.
Goals, Objectives, and Methods: The objective of the study was to provide a preliminary assessment of the effectiveness of the dam's sluiceway in passing downstream migrating juvenile salmonids. Hydroacoustic techniques were used to monitor fish near the sluiceway and spillway by strategically

mounting transducers aimed to monitor fish in the water column.
Key Findings: The sluiceway was found to provide a relatively effective means of passing downstream migrants. Based on this preliminary study the surface flow of the sluiceway was found to be more effective at passing fish than the deep flow of the spillway. Spring nighttime sluiceway operation (1800-0600 h) passed 3% of the total fish passage at the dam in 1.6% of the total water passing the dam (1.7:1 ratio). On a 24-h daily average basis, 1.6% of the total fish passage occurred through the sluiceway, in 0.3% of the total water passing the dam (5.3:1 ratio). Summer nighttime sluiceway operation passed about 4% of the total fish in 2% of the total water passing the dam (1.9:1 ration). On a 24-h daily average basis, 2.1% of the total fish passage occurred through the sluiceway, in 0.6% of the total water passing the dam (3.5:1 ratio).
During the nighttime hours (1800-0600 h) that the spillway was operated during the spring, 33% of the total fish passage at the dam passed through the spillway in 39% of the total water passing the dam (0.8:1 ratio). On a 24-h daily average basis, 21% of the total fish passage occurred through the spillway in 16% of the total water passing the dam (1.3:1 ratio). Summer nighttime spillway effectiveness passed 26% of the total fish passage at the dam passed in 18% of the total water passing the dam (1.5:1 ratio). On a 24-h daily average basis, 14% of the total fish passage occurred through the spillway in 7% of the total water passing the dam (1.9:1 ratio).
In general, vertical distributions at the powerhouse were similar for day and night with daytime observations slightly more surface oriented than the nighttime distributions. Sluiceway flow adjacent to the powerhouse did not appear to influence the vertical distribution of downstream migrants at the powerhouse. Vertical distributions at the spillway and sluiceway were similar. In spring vertical distributions at the sluiceway and spill bay 20 were more surface oriented than the distributions at spill bay 15 and 17.

4. Normandeau Associates, Inc., Parametrix, Inc., and J.R. Skalski. 1998. Response of Salmonid Smolts to a Prototype Surface Collector at Wanapum Dam, and Smolt Movement and Behavior at Priest Rapids Dam, Columbia River, Washington. Normandeau Associates, Inc., Drumore, PA.

Project: Wanapum and Priest Rapids dam
Type of Evaluation: Radiotelemetry evaluation of a prototype Surface Flow Attraction Channel (SFAC) along with movement and behavior near the Projects.
Goals, Objectives, and Methods: The objective of the study was to assess the movement and behavior of spring Chinook and steelhead approaching Wanapum Dam and in the vicinity of the prototype surface fish attraction channel (SFAC). Investigators used radio-tagged fish to assess the movement and behavior of smolts near the project.
Key Findings: High proportions of both Chinook (0.64) and steelhead (0.71) were initially detected at the upstream end of the powerhouse, which indicated that smolts approached the project along the left bank following the natural river channel. Low detection rates observed for Chinook (11%) and steelhead (23%) smolts in the vicinity of the SFAC indicate smolts were being diverted either to the units at the upper end of the powerhouse, sluiceway or spillway. The majority of Chinook (60%) and steelhead (68%) passed the project via the spillway. Some 36% and 26% of the Chinook and steelhead respectively, passed through the turbines.
The proportions of each species using the SFAC were nearly equal (about 1%). The extension of the SFAC upstream to unit 1 may have diverted fish away from the powerhouse and increased the proportion passing the spillway. Fish guidance efficiency (FGE) of the SFAC relative to all Chinook detected in the forebay with the SFAC entrance at Unit 8 was 0.0116. The respective FGE values for Chinook and steelhead smolts, which were detected in the forebay prior to passage after the SFAC entrance was moved to Unit 1 were 0.0194 and 0.0098. The low FGE estimates suggest are consistent with 1996 findings and suggest that the SFAC in its current configuration may not be a viable bypass system.
At Priest Rapids dam passage routes utilized by the Chinook and steelhead differed. More steelhead passed the spillway (55%) compared to Chinook where the majority of fish (70%) passed the turbines at Priest Rapids.

5. Ransom, B.H. 1997. Summary of Spillway and Sluiceway Effectiveness in Passing Juvenile Salmonid at Wanapum and Priest Rapids Dams From 1980-1996. Prepared for Grant County Public Utility District. Hydroacoustic Technology, Inc., Seattle, WA.

Organization: Grant County PUD
Project: Wanapum Dam and Priest Rapids Dam
Type of Evaluation: Synthesis of spillway and sluiceway passage effectiveness studies.
Goals, Objectives, and Methods: The objective of the report was to summarize the finding of spillway and sluiceway effectiveness studies at Priest and Wanapum dams from 1980 through 1996. Spillway (or sluiceway) effectiveness was calculated as the percent of all fish passage at the entire dam that passed through the spillway (or (sluiceway). Spillway (or sluiceway) efficiency was calculated as the ratio of the percent of fish passed in spill (or sluiceway), divided by the percent of total river flow passed as spill (or sluiceway).
Key Findings: Over the years of study at both projects the trend has been that sluiceway efficiency has been consistently higher than spillway, more so during spring and summer. Also daytime spillway efficiency was consistently greater than during nighttime (although nighttime fish passage rates generally exceeded daytime rates).

D.1.5.3 Priest Rapids: Multidisciplinary

4. Oakwood Consulting Inc. 2006. Summary of Hydraulic and Fish Passage Characteristics for Top-Spill Bypasses at Rock Island, Wanapum and Priest Rapids Dams. Report Submitted to U.S. Army Corps of Engineers Walla Walla District. Oakwood Consulting Inc, Belcarra, BC, Canada.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Rock Island, Wanapum, and Priest Rapids Dams
Type of Evaluation: Summary of hydraulic and fish passage characteristics
Goals, Objectives, and Methods: The objective of this paper was to summarize the topspill events at the Rock Island, Wanapum, and Priest Rapids Dams. The hydraulic and fish passage characteristics were noted for each dam.
Key Findings: Rock Island Dam: During 1996 it was determined that a narrower and deeper fish passage opening had a larger zone of influence in the forebay and drew flow from deeper depths during a topspill event. In 1997 top spill openings were constructed for fish passage. The optimal opening width was 9 ft, for a fish passage efficiency of 44.8 fish per unit of flow. In 1998 and 1999 the nappe characteristics were evaluated and the measured impact velocity on the flat apron ranged from 50 ft/s to 10 ft/s, dependent upon the tailwater depth, which varied from 5 to 50 ft, respectively. During 2000 and 2001 fish survival studies were completed while using deflectors at the end of the submerged aprons in spillbays 29 and 16. Passage through spillbay 29 was found to be benign to fish. Passage though spillbay 16 resulted in a direct survival based upon pooled data of 0.99 and 1.5% injuries. In 2005 an overflow-underflow gate that attracts fish to the surface flow while minimizing dissolved gas uptake with the bottom flow was tested for fish survival. The 48 hr survival probabilities were 1.0 for the pool aerated condition and 0.991 (for the non-aerated condition.
Wanapum Dam: In 1995 and 1996, a topspill-type bulk head was tested at both model and prototype scale. The amount of turbulence and the water level between the bulkhead and tainter gate were found to be depended on the amount the tainter gate was open. Small gate openings reduced the turbulence, but increased the water level. In addition, strong vorticity was observed between the bulkhead and the tainter gate. At flow of 2000 and 4000 cfs the 48 hr fish survival probability was 0.92 with 6.6% injury and 0.969 with 7.0% injury, respectively. In 2002 the bulkhead was modified to help streamline the approach flow. With this new design the 48 hr survival probability was 0.99 with 0.7% injury. The bulkhead was modified again in 2004 to increase the discharge and change the aspect ratio at the opening. The width was reduced and the sill elevation lowered. A tracking study showed that of the fish that came within 300 and 50 ft of the bypass 86% and 100% pass ed though the topspill, respectively.
Priest Rapids: None.

D.2 Lower Snake River Annotated Reference List

D.2.1 Lower Granite Reference List

D.2.1.1 Lower Granite: Engineering Design

1. CH2M Hill. 1997. Lower Granite Dam Behavioral Guidance Structure: Preliminary Design Report.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: Preliminary engineering design report
Goals, Objectives, and Methods: This report describes the preliminary design and selection of a behavioral guidance structure (BGS). Six alternatives were evaluated based on a matrix of performance criteria that included: scalloping and billowing; quick deployment and removal; connection of the BGS to the powerhouse or surface bypass collector; barrier incline; simplicity; avoid permanent structures in the forebay; and cost and constructability. A BGS model at ERDC (formerly WES) was used to obtain limited preliminary data for development of the design criteria during the Pre-Design. Model velocity data were collected under and along the BGS.
Key Findings: The Top Anchored/Vertical Straight Barrier alternative was selected based on high marks in all but one of the performance criteria.

2. CH2M Hill. 2000. Lower Granite Surface Bypass and Collection, Behavioral Guidance Structure Modifications for 2001 Test. Feasibility Report and Documentation. Prepared for USACE Walla Walla District.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: Feasibility report
Goals, Objectives, and Methods: The report documents the extent and cost of modifications to reposition the BGS for the 2001 test season to also include Unit 4. A schematic design of the modifications is also provided. In addition, the report also evaluates whether any modifications to the anchors are necessary to deploy the BGS in 2000, due to increased design flow conditions. Field investigations were performed to locate the positions of the anchors and clump weights, improve the accuracy of the bathymetry in the area of the BGS, and to determine the geophysical nature of the forebay bottom in the vicinity of the transverse anchors. Side scan sonar, underwater video, and sub-bottom profilers were used in the field investigations. A CFD modeling effort to characterize the flow field around the BGS is presented and to provide a basis for estimating hydraulic and environmental loads.
Key Findings: The design capacities of existing components were considered adequate to allow repositioning of the structure to the 2001 alignment. The straightness of the BGS under maximum load was found critical to minimize load sharing within the system as a result of joint rotational stiffness and anchor system stiffness. In summary, the realignment appeared feasible with a minimum amount of required modifications.

3. CH2M Hill. 2003. Lower Granite Lock and Dam, Modified BGS 2004 Prototype Hydraulic Design Document Report.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: Hydraulic documentation design report
Goals, Objectives, and Methods: The objective of this document is to describe the hydraulic rational and criteria that led to the determination of choosing a configuration for the 2004 prototype test. The

specific tasks were to investigate the hydraulics for improving fish passage and to determine hydraulic loads for evaluating feasibility for structural modifications. A detailed summary of the procedures is presented which includes key parameters for five different concepts of which one was selected for further refinements based on results from CFD modeling, numerical fish surrogate (NFS) modeling, and physical modeling. Hydraulic and environmental loads were also evaluated based on CFD model results.
Key Findings: The recommended concept for further refining into a 30% design was the 5 Unit M1-M6 Reduced Depth based on factors such as NFS model results that showed a greater fish passage through the RSW.

4. HDR and ENSR. 2000. Documentation of Hydrodynamic Conditions and Project Operation. Lower Granite Surface Bypass and Collector 2000 Prototype Tests. Prepared for USACE, Walla Walla District.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: Prototype test documentation of hydraulic conditions and project operations
Goals, Objectives, and Methods: The main objective of the project was to correlate operations of the dam with operations of the surface bypass collector (SBC) and observed fish responses in order to determine SBC/powerhouse operations that optimize collection. The goal was to develop generic relationships that help establish criteria for SBC design and operation. The main objective of the report is to provide thorough and accurate documentation of hydraulic and operating conditions that occurred during the test. Data collected during the prototype tests include flow through the SBC and fish monitoring and tracking information.
Key Findings: The report presents the collected data and possible future refinements to improve accuracy of flow evaluation.

5. Stone & Webster. 1995. Conceptual Design of 1997 Lower Granite Surface Bypass and Collection System. Development and Evaluation, Preliminary SBCS Alternatives. Prepared for USACE, Walla Walla District.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: Engineering evaluation of preliminary alternatives
Goals, Objectives, and Methods: This scope of this report was to develop and evaluate a minimum of ten preliminary concepts for a SBCS prototype at Lower Granite Dam. The purpose is to select three of these for further development. The primary decision factors in the selection are cost, maintenance requirements, effectiveness in screening fish, reliability, and certainty of performance. Some more detailed considerations include head loss through the structure, screen approach flow establishment, bypass entrance, and juvenile fish screen exposure duration. The evaluations were completed based on calculated discharges, velocities, etc. No hydraulic model study was done.
Key Findings: The recommended alternatives for further development are Alternatives 1D, 5, and 8B, based in large part on the following considerations: minimize the overall length of the dewatering structures; minimize maintenance time and cost; utilize the 1996 Prototype SBCS; and maximize the safe bypass of juvenile fish around the powerhouse.

6. Stone & Webster. 1995. Conceptual Design of 1997 Lower Granite Surface Bypass and Collection System. Final Conceptual Design Report. Prepared for USACE, Walla Walla District.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: Conceptual engineering design report
Goals, Objectives, and Methods: This report presents the preferred 1997 surface bypass collection

system (SBCS) concept. The objective of this report is to present the one conceptual SBCS design selected from *Evaluation of advanced alternatives* to the detail necessary to allow for preparation of a baseline cost estimate and schedule. The report presents hydraulic, structural, mechanical, and electrical design criteria, and a detailed description of the 1997 SBCS prototype.
Key Findings: None.

7. Stone & Webster. 1995. Conceptual Design of Lower Granite Surface Bypass and Collection System. Evaluation of Advanced Alternatives. Final Report. Prepared for USACE, Walla Walla District.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: Engineering evaluation of alternatives
Goals, Objectives, and Methods: This report presents the expanded development and evaluation of three preferred surface collector/dewatering system concepts. These alternatives were recommended for further development be the Walla Walla District based on review of *Development and evaluation of preliminary SBCS alternatives* report. A list of key design requirements is presented and comparative features are summarized in tables in each section discussing the respective alternative.
Key Findings: The recommended alternative is Alternative 3B, based on considerations such as: maximize the safe bypass of juvenile fish around the powerhouse; minimize maintenance time and expenditures; utilize the 1996 SBCS prototype; and cost and construction schedule.

10. Sverdrup, ENSR, Lund Engineering, and The Glosten Associates. 2000. Lower Granite Lock and Dam Surface Bypass and Collection Removable Spillway Weir. Pre-engineering report.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: Pre-engineering report
Goals, Objectives, and Methods: The objective of this document is to develop and integrated concept for the construction of an RSW at Lower Granite Dam. Aspects related to the design, construction, operation, function, and cost of the RSW are included. Four shapes were developed for the RSW and evaluated for hydraulic effects and fish attraction. One shape was created using standard spillway design methods (Flow Efficient Option) while the other three shapes included features deemed to be more attractive to fish (Fish Efficient Options). The four shapes were first evaluated using numerical analysis. Based upon the numerical analysis results, two shapes, the Flow Efficient Option and the Fish Efficient Option 3, were selected for scale model testing and further evaluation. Three basic options for removal and installation of the RSW were also evaluated: using vessels, using a winch system, and by sinking an RSW hinged to the dam.
Key Findings: A refined version of Fish Efficient Option 3 with the hinged to dam installation/removal system was recommended for prototype construction and testing. The design had the following advantages over the Flow Efficient Option: 1) likely to be more attractive to fish by having a greater influence into the forebay of the dam and more gradual flow acceleration; 2) simple low risk installation/removal option; 3) low operational and maintenance cost.

11. Sverdrup, ENSR, Lund Engineering, and The Glosten Associates. 2000. Lower Granite Removable Spillway Weir Decision Documentation Report. Submitted to USACE, Walla Walla District.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: engineering design documentation report
Goals, Objectives, and Methods: The objective of the report is to document the design process and related assumptions for the development of the Lower Granite Removable Spillway Weir (RSW). Provisional hydraulic guidelines were suggested and used for design of the Fish Efficient RSW. The design process included testing in a 1:25 scale physical hydraulic model at ENSR.

Key Findings: None.

12. Sverdrup Corporation, ENSR, and Hamilton Engineering, Inc. 1998. Lower Granite Lock and Dam Surface Bypass and Collection System Options Conceptual Design Report. Final Report. U.S. Army Corps of Engineers, Walla Walla, Washington.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: Conceptual engineering design report
Goals, Objectives, and Methods: This report summarizes an investigation of the engineering feasibility of installing a production surface bypass collector (SBC) system at the Lower Granite Lock and Dam. The report presents a review and comparison of ten SBC options for consideration at Lower Granite Dam. Each option was based on unique design goals and criteria which are discussed in the report. Functional descriptions for each option are provided including hydraulic operations; structural, mechanical, and electrical requirements; and operations, maintenance, and construction issues. Cost estimates are for each option are also provided.
Key Findings: The report provides only construction feasibility and cost information to assist in making an informed decision concerning a final design choice.

13. U.S. Army Corps of Engineers. 2000. Discharge and Velocity Measurements in Surface Bypass and Collector. Lower Granite Lock and Dam. USACE Walla Walla District, Walla Walla, WA.

Organization: USACE Walla Walla District
Project: Lower Granite
Type of Evaluation: Prototype test documentation
Goals, Objectives, and Methods: The objective of the report is to document the results from a survey of water surface profiles and measurements of discharge at a minimum of two gate settings. The goal was to resolve an uncertainty of discharge between the prototype and a physical model at ERDC (formerly WES). The discharge in the system was measured using an array of Price Type AA current meters. Water surface profiles were recorded using a level and rod. The document describes the equipment and data collection procedure.
Key Findings: The discharge was measured for nominal spillway discharges of 2,000 cfs, 3,100 cfs, and 4,000 cfs. In each case, the measured discharge was 11-14 percent less than expected from the spillway gate rating tables. Repeatability of the tests was excellent.

D.2.1.2 Lower Granite: Biological Evaluation

1. Adams, N., G. Johnson, D. Rondorf, S. Anglea, and T. Wik. 2001. Biological Evaluation of the Behavioral Guidance Structure at Lower Granite Dam on the Snake River, Washington in 1998. *American Fisheries Society Symposium*. 26.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Lower Granite Dam
Type of Evaluation: Biological evaluation -- hydroacoustics and radio telemetry
Goals, Objectives, and Methods: In 1998, a behavioral guidance structure (BGS; a steel wall 330 m long and 17-24 m deep,) was installed in the forebay of Lower Granite Dam on the Snake River, Washington. The purpose of the BGS was to change the horizontal distribution of downstream migrants approaching the south half of the powerhouse (Turbines 1-3) by guiding them toward the surface bypass and collector (SBC) attached to the dam upstream of the north half of the powerhouse (Turbines 4-6). The effectiveness of the BGS was evaluated using biotelemetry and hydroacoustic techniques. The BGS was designed to be movable, thereby allowing a comparison between the horizontal distribution of the fish when the BGS was deployed as a diversion devise (i.e., BGS in) and when the BGS was moved 800 m upstream of the dam and no longer influenced fish movements immediately upstream of the

powerhouse (i.e., BGS out).
Key Findings: Radio telemetry and hydroacoustic techniques showed that about 80% of the fish migrating towards Turbines 1-3 were successfully diverted north. Radio telemetry data revealed that the mean residence times of Chinook salmon (*Oncorhynchus tshawytcha*), hatchery steelhead (*Oncorhynchus mykiss*), and wild steelhead (*Oncorhynchus mykiss*) were 1.6, 1.7, and 2.4 times longer, respectively, when the BGS was out compared to when it was in. And, overall, fish passage efficiency (percentage of fish passing through non-turbine routes) was significantly (P = 0.026) higher when the BGS was in (93.7%) than out (91.2%). The authors concluded that the BGS concept appeared to be valid. However, only two of the three turbines located behind the BGS were functioning during the test. Additional flow behind the BGS might change its effectiveness.

9. Anglea, S.M., K.D. Ham, G.E. Johnson, M.A. Simmons, C.S. Simmons, E. Kudera, and J. Skalski. 2003. Hydroacoustic Evaluation of the Removable Spillway Weir at Lower Granite Dam in 2002. Final. PNWD-3219.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Lower Granite Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: In 2002, the Corps removed the SBC from Bay 1 and installed a prototype surface spill SFO at Lower Granite Dam called the Removable Spillway Weir (RSW). The premise of the RSW was that a high flow (>5,000 cfs) surface outlet with gradual water acceleration in its forebay flow net will enhance spill passage effectiveness, thereby increasing non-turbine passage and improving project survival. The RSW at Lower Granite Dam has a smooth-crested weir and specially shaped entrance that is 50 ft wide and about 10 ft deep at the crest (723 ft MSL) at the minimum operating pool elevation of 733 ft MSL. Design discharge through the RSW is 6,000 to 11,000 cfs; discharge averaged 6,900 cfs during the 2002 evaluation.
The goal of this study was to evaluate the performance of the RSW. During the study, the SBC, Simulated Wells Intake, and BGS were in place, as was the trash-shear boom. The intent was to test the three RSW/spill treatments in a randomized block experimental design. However, the treatment schedule and operational conditions were satisfied only intermittently because of forced spill due to turbine unit outages and occasional high runoff. As a consequence, the randomized block design required to statistically analyze treatment effects was attained consistently only from May 9 to 19, 2002. The authors used fixed hydroacoustic techniques to sample fish passage and estimate combined RSW+spill passage efficiency from April 15 to June 6, 2002.
Key Findings: Fish movement toward and into the RSW occurred at all depths sampled (0-20 ft deep) just upstream of the RSW, even 10 ft below the entrance. There was also a pronounced upward trajectory of fish into the RSW from depths below the weir crest. On a seasonal basis, the proportion of combined RSW+spill passage out of total project passage (CY) was 0.83. Combined spill effectiveness (CS) was 2.2. The proportion of RSW passage out of total project passage was 0.46. RSW effectiveness (fish: flow ratio) was 8.7. Spill effectiveness (Bays 2-8 only) was 1.1. The authors concluded that the 2002 evaluation at Lower Granite Dam demonstrated that an RSW-type surface flow bypass is an effective fish passage tool that increases the range of options available to fish and hydrosystem managers.

13. Cash, K. and five co-authors. 2005. Three-Dimensional Fish Tracking to Evaluate the Removable Spillway Weir at Lower Granite Dam During 2003. Final Report Prepared for the Walla Walla District, U.S. Army Corps of Engineers. USGS.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project : Lower Granite Dam
Type of Evaluation: Biological evaluation - acoustic telemetry
Goals, Objectives, and Methods: The goal of this study, which complements that of Plumb et al. (2004), was to assess how juvenile salmonid behavior influenced performance of the RSW. The

objectives were to: 1) evaluate fine-scale, species-specific fish behavior immediately upstream of the RSW by using a 3D fish tracking system, and 2) analyze behavior of juvenile salmonid migrants in relation to discharge, dam operations, and flow patterns described by a computational fluid dynamics model. Test treatments were RSW off with spill to the "gas cap" and RSW on with about 12 kcfs training spill. The authors tagged with acoustic transmitters and released 198 juvenile hatchery steelhead, 198 juvenile wild steelhead, and 198 juvenile hatchery Chinook salmon.
Key Findings: Overall, including times when the RSW was closed for the gas cap spill treatment, RSW passage efficiencies were 39.1% for all hatchery steelhead, 36.4% for all wild steelhead, and 39.7% for all Chinook salmon. Of the fish detected within 30 ft of the RSW, entrance efficiencies were 87.9% for hatchery steelhead, 89.6% for wild steelhead, and 96.0% for Chinook salmon. The authors also reported volumetric RSW passage efficiency, i.e., the percentage of fish detected within a specific bin that passed the RSW of the total number of fish detected within the bin. In addition, they observed fish moving upward from relatively deep approach paths to pass through the RSW. Interestingly, the trash-sheer boom was seemingly effective at diverting and guiding fish.

17. Dawson, J., M. Burger, and M. Dinsmore. 2006. Hydroacoustic Evaluation of Fish Passage at Lower Granite Dam Associated With the Prototype Removable Spillway Weir, 2005. Final Report Prepared for the Walla Walla District, U.S. Army Corps of Engineers. BioSonics, Inc.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Lower Granite Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: The authors used fixed hydrocoustics to monitor fish passage at Lower Granite Dam during April 10-June 2 June 19-July 21, 2005. The objectives of the study were to estimate fish passage efficiencies (FPE, FGE, spillway, and RSW) and distributions (vertical, horizontal, diel, run timing). The study occurred during a low-flow year. The RSW was not opened until the end of April. Training spill for the RSW was variable during spring. During the summer study, all water in excess of that required for station service was spilled. The RSW was opened/closed periodically during the summer study on approximately a 24 or 48-hour cycle.
Key Findings: Passage efficiency data were reported as follows (extracted from table on from p. 1):

	Spring	Summer
Spill Efficiency	0.31	0.75
Spill Effectiveness	3.9	1.52
RSW Efficiency	0.31	0.25
RSW Effectiveness	11.28	3.27
Fish Passage Efficiency	.94	.99
Fish Guidance Efficiency	.85	.81

19. Johnson, G.E., N.S. Adams, R.L. Johnson, D.W. Rondorf, D.D. Dauble, and T.Y. Barila. 2000. Evaluation of the Prototype Surface Bypass for Salmonid Juvenile Salmonids in Spring 1996 and 1997 at Lower Granite Dam on the Snake River, Washington. Trans. Am. Fish. Soc. 129: 381-397.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project : Lower Granite Dam
Type of Evaluation: Biological evaluation -- hydroacoustics and radio telemetry
Goals, Objectives, and Methods: In spring 1996 and 1997, the authors studied the prototype surface bypass and collector (SBC) at Lower Granite Dam on the Snake River. Their objectives were to

determine the most efficient SBC configuration and to describe smolt movements and swimming behavior in the forebay. To do this, they used hydroacoustic and radio telemetry techniques. The SBC was retrofit onto the upstream face of the north half of the powerhouse to test the surface bypass method of diverting smolts from turbines. The SBC had three entrances with mean velocities ranging from 0.37 to 1.92 m/s and discharged 113 m^3/s through its outlet at Spill Bay 1, adjacent to the powerhouse. Different SBC configurations were created by altering the size and shape of entrances. **Key Findings**: During spring 1996 and 1997, river discharge was well above normal (123% and 154% of average, respectively). Powerhouse operations caused a strong downward component of flow upstream of the SBC. Many smolts (comprised of primarily steelhead and secondarily Chinook salmon) were observed actively swimming upward in the water column. There were four times as many smolts diverted from turbines per unit volume of water with SBC flow than spill flow. Because of this, the authors felt the SBC may be an especially important bypass consideration in moderate or low flow years. The highest SBC efficiency (the proportion of total fish passing through the north half of the powerhouse by all routes that passed through the SBC) for any configuration tested was about 40%. The authors concluded that, although no single SBC configuration stood out as the most efficient, the Horizontal Surface and Maximum Area configurations, or some combination, are worth further investigation because they were moderately efficient.

20. Johnson, G.E. and D.D. Dauble. 1995. Synthesis of Existing Physical and Biological Information Relative to Development of a Prototype Surface Flow Bypass System at Lower Granite Dam. Final report. Submitted to CENWW, Walla Walla, Wa. PNNL.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Lower Granite Dam
Type of Evaluation: General review and synthesis
Goals, Objectives, and Methods: This paper synthesized available information to help guide design of the SFO prototype at Lower Granite Dam. This prototype, called the Surface Bypass and Collector (SBC), was installed at the dam in 1996. This review of over 120 available reports and publications concerning biological and physical characteristics of the reservoir, forebay, and dam.
Key Findings: The authors found that the state of available information was reasonably well-known for bathymetry, temperature profiles, temporal and spatial distributions of smolts, and the relative abundance of predators. Information is poorly known for forebay water velocity and acceleration, smolt behavioral response to hydraulic conditions, smolt delay in the forebay, effects of smolt physiology on passage, and temporal abundance of predators. The authors noted that the proposed SFO would not provide increased fish passage efficiency unless it intercepts fish otherwise sound and pass in turbines. They cautioned that the concept of attraction flow appeared to be valid only in a limited area of the forebay. However, given that downstream migrants, especially yearling smolts, tend to follow the thalweg and are distributed in the upper water column when they reach LGR, it seemed likely to these authors that the fish would encounter a SFO prototype located near the junction of the powerhouse and spillway. The authors concluded (p. 29) "…SFB has potential to improve downstream passage conditions at Lower Granite Dam."

24. Johnson, G.E., S.M. Anglea, N.S. Adams, and T.O. Wik. 2005. Evaluation of The Prototype Surface Flow Bypass for Juvenile Salmon and Steelhead at The Powerhouse of Lower Granite Dam, Snake River, Washington, 1996-2000. *N. Amer. J. Fish. Management*. 25.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Lower Granite Dam
Type of Evaluation: Review and synthesis
Goals, Objectives, and Methods: The surface bypass and collector (SBC) was retrofit on the face of the Lower Granite powerhouse and tested during 1996-2000. The objectives were to 1) establish proof-of-concept for surface flow bypass at the lower Snake River dams; 2) identify the best of 11 SBC entrance configurations and describe its main structural and hydraulic characteristics from a biological point of

view; and 3) evaluate species-specific and project-wide performance of the SBC in terms of efficiency (proportion of fish using the SBC out of total passage) and effectiveness (ratio of the proportion of fish using the SBC to the proportion of water discharged through the SBC). The authors synthesized hydroacoustic and radio telemetry data from annual studies during the five-year evaluation period.
Key Findings: The best tested entrance configuration had maximum inflow (99 m^3/s) concentrated in a single surface entrance (5 m wide and 8.5 m deep). The researchers identified five important considerations for future surface flow bypass development in the lower Snake River and elsewhere: 1) form an extensive flow net in the forebay using relatively high surface flow bypass discharge (> ~7% of total project discharge); 2) create a gradual increase in water velocity approaching the surface flow bypass (ideally, acceleration < 1 m/s/m); 3) make water velocities at an entrance high enough (> 3 m/s) to entrain the subject juvenile fishes; 4) adapt the shape and orientation of the surface entrance(s) to fit site-specific features; 5) consider a forebay wall to increase fish availability to the surface flow bypass. SBC efficiency was not high enough (maximum 62% relative to Turbine Units 4-5) for it to be a stand-alone bypass. The authors concluded that anywhere surface-oriented anadromous fish must negotiate hydroelectric dams, surface flow bypass systems can provide cost-effective use of typically limited water supplies to increase non-turbine passage, and presumably survival, of downstream migrants.

30. Normandeau Associates, Inc., J.R. Skalski, and Mid Columbia Consulting, Inc. 2002. Passage Survival and Fish Condition at the Removable Spillway Weir at Lower Granite Dam, Snake River. Final.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Lower Granite Dam
Type of Evaluation: Biological evaluation - balloon tag, mark-recapture
Goals, Objectives, and Methods: The goal of this study was to estimate survival and condition of juvenile salmon passing through the RSW at Lower Granite Dam. The study methods involved tagging hatchery-reared Chinook salmon (120 to 192 mm, average about 152 mm total length) with balloon tags. A total of 260 fish were released at the RSW in Spill Bay 1. An additional 130 fish (secondary treatment) were released through the Spill Bay 2 tainter gate to separate RSW passage effects from spill bay passage effects. About 130 control fish were released downstream of the discharge from Spill Bay 1. Discharge rates through Spill Bays 1 and 2 were approximately 7,000 and 5,700 cfs, respectively.
Key Findings: Adjusted for tailrace controls, the estimated 1-h and 48-h survival probabilities for RSW fish were 0.992 and 0.981 (90% CI=0.983 to 1.000 and
0.966 to 0.995) respectively. The estimated 1-h and 48-h survival probabilities for Spill Bay 2 fish, adjusted for tailrace controls, were 1.00 and 1.00 respectively. The injury rate for smolts passed through the RSW were similar to the rate observed in Spill Bay 2 (1.5% vs. 2.3%) but 75% of the RSW injuries were classified as major while all Spill Bay 2 injuries were minor.

33. Plumb, J. and ten co-authors. 2004. Behavior and Survival of Radio-Tagged Juvenile Chinook Salmon and Steelhead Relative to the Performance of a Removable Spillway Weir at Lower Granite Dam, Washington, 2003. Final Report of Research Submitted to CENWW. USGS.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Lower Granite Dam
Type of Evaluation: Biological evaluation
Goals, Objectives, and Methods: The 2003 RSW evaluation at Lower Granite Dam continued RSW research initiated in 2002. A main difference between the two study-years was that the old SBC/SWI was removed from the powerhouse and the BGS was not deployed in 2003. The intent was to create a "stand-alone" RSW. The study goal was to evaluate RSW performance with objectives to: 1) estimate fish passage efficiencies during RSW+14 kcfs training spill vs. gas cap spill, 2) determine how dam operations may affect RSW performance, 3) assess species-specific differences in behavior relative to RSW operation, and 4) estimate and compare the survival of juvenile hatchery spring Chinook salmon passing through the RSW to those passing during gas cap spill. The authors surgically implanted radio tags and released 1,260 hatchery spring Chinook salmon, 399 hatchery steelhead, and 399 wild

steelhead. They monitored passage at the dam from April 14 to June 9, 2003.
Key Findings: During the RSW treatment, median passage times and the percentage of fish traveling upriver from the dam were low. During the gas cap treatment, median passage times were more than double those during the RSW treatment and the percentage of fish traveling upriver from the dam was three fold higher for hatchery Chinook salmon and twice as high for hatchery steelhead during the gas cap treatment compared to the RSW treatment. These differences in fish behavior between the treatments were statistically significant (P < 0.025). During the RSW treatment, the RSW passed 58-69% of fish and "training" spill passed just 4-8% of fish. During the gas cap treatment, spill passed 52-59% of the fish. Passage effectiveness (%fish/%water) for the RSW was 8.39.9 compared to 1.6-1.8 for gas cap spill. Using the paired release-recapture model to calculate survival probabilities for juvenile hatchery spring Chinook salmon that passed through the RSW or spill to the gas cap, the authors estimated survival was 0.980 ±0.023 (mean ± 95% confidence interval) for fish passing through the RSW and 0.931 ±0.060 for fish passing through spill during the gas cap treatment. However, this difference was not significant (P=0.11). The authors concluded "…the RSW likely reduced passage times, reduced the percent of fish traveling upriver from the dam, and passed a higher percentage of fish than all other routes while using less water. We found no difference in survival probabilities between treatments, suggesting the RSW posed few adverse affects on survival relative to gas cap spill."

34. Plumb, J.M., A.C. Braatz, J.N. Lucchesi, S.D. Fielding, J.M. Sprando, G.T. George, N.S. Adams, and D.W. Rondorf. 2003. Behavior of Radio-Tagged Juvenile Chinook Salmon and Steelhead and Performance of a Removable Spillway Weir at Lower Granite Dam, Washington, 2002. Draft. W68SBV00104592.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Lower Granite Dam
Type of Evaluation: Biological evaluation - radio telemetry
Goals, Objectives, and Methods: This study assessed the performance of the new RSW at LGR in 2002. It was a companion study to Anglea et al. (2003). The goal was to evaluate passage of radio-tagged juvenile salmonids though Lower Granite Dam and the new RSW in 2002. A primary objective was to assess fish passage with RSW open in conjunction with "training" spill vs. RSW closed with gas cal spill. The three realized study-treatments were RSW+10 kcfs spill, RSW+18 kcfs spill, and "gas cap" (no RSW+42 kcfs spill). The authors surgically implanted radio transmitters in 788 Chinook salmon, 387 hatchery steelhead, and 389 wild steelhead. The study period was April 14 to June 9, 2002.
Key Findings: The majority of fish approached the dam at the north side of the forebay. The difference in median residence times (period from first detection to passage) for Chinook salmon among RSW treatments was small; however, the median passage times were four times greater for hatchery steelhead and two times greater for wild steelhead when the RSW was off as compared to when it was on. Of all fish detected in the forebay, about half were detected within 6 m of the RSW Chinook salmon (50%), hatchery steelhead (56%), and wild steelhead (55%). Of these fish, RSW entrance efficiencies were 89% of Chinook salmon, 96% of hatchery steelhead, and 90% of wild steelhead. In comparison, during 2000, entrance efficiencies for the SBC ranged from 40-69% (Plumb et al. 2002). As spill discharge ranged from 10-83 kcfs, the percentage of fish passing into the RSW decreased from 68 to 27% for Chinook salmon, 61to 16% for hatchery steelhead, and from 68 to 27% for wild steelhead. Overall, the RSW discharged just 8.5% of the total discharge through the dam, but on average passed 56-62% of radio-tagged fish determined to pass Lower Granite Dam in 2002. The authors concluded that the RSW was a "…relatively effective and efficient passage enhancement structure."

D.2.1.4 Lower Granite: Physical Modeling

2. ENSR and Sverdrup. 2000. Hydraulic Model Study of Removable Spillway Weir for Juvenile Fish Passage at Lower Granite Dam. Final Report. Prepared for U.S. Army Corps of Engineers Walla Walla District. ENSR document no. 6455-023-460.

Organization: USACE Walla Walla District
Project: Lower Granite Dam
Type of Evaluation: Physical model study
Goals, Objectives, and Methods: A 1:25 scale physical model study of one spillbay was used to support development of a removable spillway weir (RSW) at Lower Granite. The flow conditions over the RSW and on the RSW-to-spillway transition were considered as were the hydraulic conditions during operation of the spillway gate to turn the RSW on or off. Pressure measurements on the RSW and spillway gate were taken for use in estimating the hydraulic load on both the RSW and the gate. The performance of the RSW was evaluated against preliminary hydraulic design guidelines such as location, discharge, zone of influence, and approach velocity gradient. Three RSW designs were investigated: 1) Flow Efficient RSW, designed to be hydraulically efficient; 2) Fish Efficient RSW, designed with efficient fish passage as most important consideration; and 3) Fish Efficient RSW(3), a slightly modified Fish Efficient RSW.
Key Findings: Alternative 3, the Fish Efficient RSW(3) design was tested in more detail and selected for prototype construction and testing. The Fish Efficient design met the preliminary hydraulic design guidelines. The report recommends further investigations of the shock waves adjacent to the piers and also of the approach velocity gradient.

D.2.1.5 Lower Granite: Multidisciplinary

1. Anglea, S.M., G.E. Johnson, T.O. Wik, L.A. Reese, and A.E. Giorgi. 2002. Development of the Surface Bypass and Collector for Juvenile Salmon and Steelhead at Lower Granite Dam, 1994-2000. Final report submitted to U.S. Army Corps of Engineers, Walla Walla District.

Organization: USACE Walla Walla District
Project: Lower Granite Dam
Type of Evaluation: Synthesis document of results of several studies from 1994-2000 to develop and evaluate a prototype surface bypass and collector system at Lower Granite Dam.
Goals, Objectives, and Methods: This report summarizes annual (1994-2000) investigations of a surface bypass and collector (SBC) at Lower Granite Dam. The objectives of the SBC program between 1994 and 2000 were to 1) provide information on SBC performance to the Feasibility Report and Environmental Impact Statement on juvenile salmon migration in the Lower Snake River and 2) develop a SBC configuration to apply to Lower Granite and potentially other Columbia Basin dams. The report describes the hydraulic engineering, biological monitoring, SBC configurations, experimental designs, and data analysis metrics for the SBC program. Development of the SBC was based on an adaptive learning process from year to year. The report contains sections of references and annotated references.
Key Findings: The report summarizes its conclusions as: 1) the original objectives for the SBC program were met; 2) the SBC was the most effective passage route in terms of number of fish passed per unit of water; 3) turbine loading was inversely related to SBC efficiency; 4) the Ice Harbor and Single Chute were promising entrance configurations; 5) the BGS successfully diverted fish away from the three turbine units behind it at Lower Granite Dam; 6) the simulated Wells intake (SWI) was apparently effective as a turbine intake and occlusion device; and 7) the SBC, in combination with spill and/or intake screen bypass systems, provide for efficient non-turbine passage.

D.2.2 Lower Monumental Reference List

D.2.2.1 Lower Monumental: Biological Evaluation

4. Smith, J.R. 1974. Distribution of Seaward-Migrating Chinook Salmon and Steelhead Trout in the Snake River Above Lower Monumental Dam. Marine Fisheries Review 36(8): 42-45.

Organization: National Marine Fisheries Service
Project: Lower Monumental Dam

Type of Evaluation: Biological evaluation - gill net
Goals, Objectives, and Methods: The primary objective of this study was to obtain species-specific data on the vertical distribution of juvenile salmonids migrating downstream in waters that at times can have high levels of potentially lethal total dissolved gas. Because fish can compensate for excess saturation (over 100%) by swimming deeper in the water column, vertical distribution data are important to understand the effects of total dissolved gas super-saturation on smolt survival. The basic method was fishing with variable mesh gill nets 0.5-0.75 miles upstream of LMO. Nearshore and offshore sites were sampled day and night separately from April 23 to May 25, 1973. Gill net panels 20 ft long and 12 ft deep were moved up and down at the sample sites to cover the total vertical sample depth (nearshore, 0-48 ft and offshore, 0-96 ft; see Figure 1, p. 43).
Key Findings: Combining catches from the nearshore and offshore sites, 58% of the Chinook salmon and 36% of the steelhead were migrating in the upper 12 ft of the forebay. Approximately 92% and 76% of the juvenile Chinook salmon and steelhead, respectively, were collected between dusk and dawn. As the authors noted, however, this observation may have been biased by the tendency of gill nets to have higher capture efficiency during low visibility. The juvenile Chinook salmon tended to be more surface-oriented during night than day, whereas the opposite was true for juvenile steelhead. Juvenile steelhead were reasonably uniformly distributed between the nearshore and offshore sample sites; however, juvenile Chinook salmon clearly were more prevalent at the offshore site. This study is important to SFO developers because it is one of the few to get direct, species-specific vertical and horizontal distribution data in the reservoir upstream of a potential SFO site.

D.2.2.2 Lower Monumental: Physical Modeling

1. ENSR. 2005. Hydraulic Model Study of Removable Spillway Weir for Juvenile Fish Passage at Lower Monumental Dam. 90% Report. Prepared for U.S. Army Corps of Engineers Walla Walla District. ENSR document no. 09000-365-2720.

Organization: USACE Walla Walla District
Project: Lower Monumental Dam
Type of Evaluation: Physical model study
Goals, Objectives, and Methods: This report documents the results of a hydraulic model study of a removable spillway weir (RSW) designed for Lower Monumental Dam. Three different designs were investigated: 1) a design similar to the Ice Harbor RSW; 2) a design similar to the Lower Granite RSW; and 3) a design similar to Ice Harbor RSW but with a steeper ogee slope to reduce the overall size and construction cost of the structure. The performance of each RSWs was documented both qualitatively with photos and video and quantitatively by collecting approach velocity, RSW and spillway pressure, and discharge data. The effect on spillway discharge capacity with the RSW in stored position on the reservoir bottom was also investigated.
Key Findings: RSW 1 performed the best and was recommended for prototype construction and testing. The frequency and magnitudes of shockwaves on the spillway were significantly reduced compared to other alternatives. There was no significant effect on spillway discharge capacity with the RSW in stored position.

D.2.3 Ice Harbor Reference List

D.2.3.1 Ice Harbor: Engineering Design

1. Jacobs Civil, Inc. 2004. Design Documentation Report, BCOE Submittal. Prepared for U.S. Army Corps of Engineers Walla Walla District.

Organization: USACE Walla Walla District
Project: Ice Harbor Dam
Type of Evaluation: Engineering design documentation of removable spillway weir

Goals, Objectives, and Methods: The objective of the report is to document the design process and related assumptions for the development of the Ice Harbor Removable Spillway Weir (RSW). Three shapes were developed in the process. One mimicked the Lower Granite RSW, while the other two included features deemed to have better hydraulic conditions on the downstream side of the RSW crest. The shapes were first evaluated using the hydraulic model of Ice Harbor available at ERDC in Vicksburg, MS. Two of the shapes were subsequently tested in a larger scale physical hydraulic model at ENSR in Redmond, WA.
Key Findings: The second shape, Alternative 2, was clearly superior to Alternative 1 and was selected as the shape to carry forward into final design.

D.2.3.2 Ice Harbor: Biological Evaluation

2. BioSonics, Inc. 1995. Executive Summary and Split-Beam Fish Tracking Results From the Report: Acoustic Evaluation of the Surface Bypass and Collection System at Ice Harbor Dam in 1995. Final Report Submitted to CENWW, Walla Walla, WA. BioSonics, Inc.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Ice Harbor Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics and sonar tracker
Goals, Objectives, and Methods: The Corps performed SFO prototype research at Ice Harbor in 1995 before the sluiceway was closed in 1996 to install an intake screen smolt bypass system. The intent was to use the sluiceway as a field laboratory to provide information pertinent to SFO development efforts at Lower Granite Dam where field installations and testing were scheduled for the following year. The 1995 SFO at the Ice Harbor powerhouse was comprised of the existing sluiceway with and without reconfigured entrances. A reconfigured entrance had a vertical slot retrofit on the dam over a sluice gate entrance. This was done at locations 1A and 4B. These SFO prototype structures were designed to deepen the area of influence of a sluice gate. Overall there were four SFO test conditions at the powerhouse in 1995:

- Vertical Slot 1A narrow (4 ft wide and 40 ft deep) at 2 fps entrance velocity
- Vertical Slot 1A narrow at 4 fps entrance velocity
- Vertical Slot 4B wide (6 ft wide and 40 ft deep) at 4 fps entrance velocity
- Sluice Gate 2B (20 ft wide and 6 ft deep) at 7.5 fps

The primary objective of this study was to evaluate the efficiency (proportion passed) and effectiveness (fish per unit flow) of sluice gates reconfigured with vertical slot entrances compared to existing sluice entrances. Secondary objectives were to characterize fish movement patterns and behaviors immediately upstream of the SFO entrances, estimate vertical, horizontal and diel distributions, and compare top vs. bottom spill. Study methods involved fixed location hydroacoustics and a new invention, the sonar tracker.
Key Findings: In 1995 prototype SFO tests at Ice Harbor, vertical distribution at the powerhouse showed that fish were most abundant 2 to 6 m deep, somewhat less abundant between the surface and 2 m and 6 m and 10 m, then below 10 m abundance decreased rapidly. Thus, fish were surface-oriented and presumably had the opportunity to discover the SFO. However, we do not have entrance efficiency data from either the radio telemetry or hydroacoustic studies as currently reported to assess opportunity for discovery. BioSonics (1996) reported that fish densities (fish per unit volume of water) were 6 to 20 times higher in SFO discharge, whether vertical slot or regular sluice gate, than the project average. This implies some smolts had the opportunity to discover the SFO. Overall SFO efficiency (proportion of total population passing the dam that entered and passed through the dam in the SFO) was about 20%, based on hydroacoustic data. About 70% of total passage was through the spillway and 10% was through the turbines. Apparently many smolts did not have an opportunity to discover the SFO because spill passed such a large proportion of the outmigrant population, as was suspected at Lower Granite in 1996 (Johnson et al. 1999). The authors noted that regular sluice gate surface skim “consistently had the highest fish passage rates and bypass efficiencies..” The experimental design, however, did not allow the researchers to statistically separate effects of location (1A, 2B, 4A) from SFO configuration. Entrance

efficiency (percentage of fish that enter the SFB out of the total "available", i.e., the total that encounter the SFB) was not estimated in the 1995 hydroacoustic study. The SFO strategy of blocking trashracks and installing reconfigured sluiceway entrances did not apparently enhance sluiceway performance as they were designed to. Johnson et al. (1997) hypothesized that the vertical slots had relatively poor entrance conditions. At the spillway, top spill was 2 times more effective than deep spill at passing downstream migrants. The sonar tracker data showed that fish could be tracked and fish movements and behaviors described qualitatively; however, development work was necessary to reduce and analyze the data quantitatively.

3. Johnson, L., C. Noyes, and G.E. Johnson. 1982. Hydroacoustic Evaluation of the Efficiency of the Ice Harbor Dam Ice and Trash Sluiceway for Passing Downstream Migrating Juvenile Salmon and Steelhead, 1982. Volume I. Final Report. BioSonics, Inc., Seattle, Washington.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Ice Harbor Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics and fyke net
Goals, Objectives, and Methods: The goal of this study was to evaluate the sluiceway as a potential juvenile salmonid bypass system under varying operational and environmental conditions. The objectives were to compare net and acoustic counts, describe vertical, horizontal, diel, and run timing distributions, estimate sluiceway passage efficiency (proportion of fish entering the powerhouse that used the sluiceway) and effectiveness (fish per unit volume of water) for sampled areas at the sluiceway, turbine, and spill bay. Hydroacoustic transducers sampled fish passage into the sluice entrances (4 of 4), turbine units (6 of 6), and spill bays (2 of 8). In addition, an array four fyke nets sampled 100% of the water flowing into Sluice Gate 3C. The simultaneous hydroacoustic and fyke net data at Gate 3C were used to derive an empirical expansion coefficient for hydroacoustic data at the sluiceway. Data were collected from April 22 to May 28, 1982.
Key Findings: The correlation coefficient of 0.96 between net and acoustic counts (n=26) at Sluice Gate 3C was significant (P<0.001). (That's right, r=0.96.) Juvenile yearling Chinook salmon and steelhead were the predominant migrants, with mean standard lengths of 127 mm and 174 mm, respectively. Vertical distribution was shallower during daylight than darkness. Fish passage rates at the sluiceway were highest during the day; the opposite was observed for turbine passage. Sluiceway efficiency relative to the powerhouse was estimated to be 24%. Effectiveness (fish density) was an order of magnitude higher at the sluiceway than turbine or spill bay sample locations.

4. Johnson, L., C. Noyes, and R. McClure. 1983. Hydroacoustic Evaluation of the Efficiencies of the Ice and Trash Sluiceway and Spillway at Ice Harbor Dam for Passing Downstream Migrating Juvenile Salmon and Steelhead, 1983. Volume I. Draft Report. BioSonics, Inc., Seattle, Washington.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Ice Harbor Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: This study continued research initiated in 1982 on the IHR sluiceway. A goal of this study was to establish optimum sluiceway operating conditions. (The study also included research at the spillway that is beyond the scope of this annotation.) The objectives included estimating sluiceway passage efficiency relative to the powerhouse and comparing sluiceway efficiency for two sluice gate configurations: 3-open gates vs. 6-open gates. Total sluiceway discharge was about 2,700 cfs for both configurations. Hydroacoustic sampling was conducted 24 h/d from April 15 to May 27, 1983.
Key Findings: Sluiceway efficiency relative to the powerhouse was estimated to be 52%. This estimate was over twice that in 1982 (sluiceway efficiency re: powerhouse = 24%). The authors offered two reasons for this difference in sluice efficiency between 1983 and 1982: greater sluiceway discharge (2,700 vs. 1,400-2,100 cfs) and a higher proportion of yearling Chinook in the total outmigration (79% vs. 56%) which they surmised were more apt to pass in sluice flow than steelhead. There was no difference in sluiceway efficiency between the 3-open gate and 6-open gate configurations. The authors noted that

sluice gates seem to pass more fish when gates are opened above operating turbines as opposed off-line turbines. The authors concluded (p. 28) that "…further increases in [sluiceway] efficiency at Ice Harbor Dam may not be possible without modifications allowing higher sluiceway flow (2700 cfs was the maximum allowable in 1983)."
Ultimately, the Region decided that a submersible traveling screen system in the turbine intakes, instead of a sluiceway SFO, was the preferred juvenile salmonid protection system at Ice Harbor. Building this screen bypass system necessitated closing off the IHR sluiceway in 1996.

7. Swan, G.A., M.B. Eppard, E.E. Hockersmith, B.P. Sandford, B.L. Iverson, P.A. Ocker, M.A. Kaminski, and R.N. Iwamoto. 1997. Juvenile Radio-Telemetry Study at Ice Harbor Dam, 1995. Annual Report of Research. Draft.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Project: Ice Harbor Dam
Type of Evaluation: Biological evaluation - radio telemetry
Goals, Objectives, and Methods: This is a companion study to BioSonics (1996). Swan, et al. (1997) used radio telemetry during the 1995 prototype SFB test to study movement and passage of 170 hatchery yearling Chinook salmon (88 spring and 82 fall stock individuals combined) and 44 hatchery yearling steelhead. Between early May and mid-June 1995, fish were tagged and released 1-3 miles upstream of IHR.
Key Findings: Sixty-two percent of the tagged fish were detected at IHR. But, only 16 radio-tagged steelhead were detected at the dam. Of the 53 radio-tagged Chinook known to have entered the sluiceway, 57% used the regular surface skim sluice gate at 2B and only 5% and 2% used vertical slots at 1A and 4B, respectively. Similar surface preference was observed at the spillway. The authors said (p. v), "..radio-tagged juvenile salmonids preferred a surface collector design which utilized a surface skim rather than a deep draw. Also, spillway passage efficiency was significantly higher for surface skim compared to deep draw under the tainter gates."

D.2.3.3 Ice Harbor: Physical Modeling

1. ENSR. 2004. Hydraulic Model Study of Removable Spillway Weir for Juvenile Fish Passage at Ice Harbor Dam. Final Report. Prepared for U.S. Army Corps of Engineers Walla Walla District. ENSR, Redmond, WA. ENSR document no. 06455-030-2511.

Organization: USACE Walla Walla District
Project: Ice Harbor Dam
Type of Evaluation: Physical model study of removable spillway weir (RSW).
Goals, Objectives, and Methods: The objective of the report is to document the hydraulic performance of the tested RSWs. A 1:25 scale physical model at ENSR in Redmond, WA, was used to hydraulically investigate two RSW alternative, designated Alternatives 1 and 2. The model data results were compared to hydraulic performance guidelines adopted from the Lower Granite RSW design documentation.
Key Findings: The results show that Alternative 2 performed the best. The shockwaves, originating from the RSW pier noses, on the spillway were significantly reduced with Alternative 2. The performance guidelines were all satisfied.

D.3 Lower Columbia River Annotated Reference List

D.3.1 McNary Reference List

D.3.1.1 McNary: Physical Modeling

1. ENSR. 2006. Hydraulic Model Study of McNary Dam Surface Fish Bypass. 90% Report. Prepared for

U.S. Army Corps of Engineers Walla Walla District. ENSR document no. 09000-387-2620.

Organization: USACE Walla Walla District
Project: McNary Dam
Type of Evaluation: Physical model study
Goals, Objectives, and Methods: This report documents the results of a hydraulic model study of a temporary spillway weir (TSW) designed for Lower Monumental Dam. Three different designs were investigated and designated TSW 1, TSW 2a, and TSW 2b. The performance of each RSWs is documented both qualitatively with photos and video and quantitatively by approach velocity, TSW and spillway ogee pressure, water surface profiles, and discharge measurements. The nappe impact on the spillway ogee is also characterized hydraulically and presented in the text.
Key Findings: The approach velocity field is shown to be similar to the model RSWs tested for Lower Monumental and Ice Harbor. The nappe impact hydraulic conditions were the best with TSW 2b, due to the flatter nappe trajectory and smaller impact angle with the spillway ogee. The results show very good correlation of measured impact pressures to calculated pressures and backroller size. The collected data showed it was not possible to predict the trajectory of the nappe lower water surface and the location of its impact on the spillway ogee from the physical model data. The report suggests a CFD model may be able to predict the lower nappe trajectory from which backroller size and impact pressures can be estimated. Finally, the report recommends TSW 2b be selected for prototype installation and field testing.

D.3.2 John Day Reference List

D.3.2.1 John Day: Engineering Design

1. CH2M Hill, Montgomery Watson, Northwest Hydraulic Consultants, The Glosten Associates, and Civil Tech. 2001. John Day Surface Bypass Removable Spillway Weir. Design Documentation Report No. 53.

   Organization: USACE Portland District
   Project: John Day Dam
   Type of Evaluation: Engineering design documentation of removable spillway weir.
   Goals, Objectives, and Methods: The objective of the report is to document the design process and related assumptions for the development of the John Day Dam Removable Spillway Weir (RSW). Seven alternative shapes were developed in the process, four of which were evaluated in a sectional hydraulic model provided by northwest hydraulic consultants and two of which were investigated in the general physical hydraulic model at ERDC in Vicksburg, MS.
   Key Findings: A preferred RSW alternative was selected based on physical model study results. Plans and specifications were developed and a total cost was estimated.

2. Harza and ENSR. 1996. Surface Bypass Alternatives at Bonneville, The Dalles, and John Day Spillways, Final Report, Vol. 1.

   Organization: USACE Portland District
   Project: John Day Dam
   Type of Evaluation: Engineering evaluation of surface bypass alternatives.
   Goals, Objectives, and Methods: Alternatives for surface bypass of juvenile salmon at the John Day powerhouse are described in this report. Three alternatives were selected for surface bypass concepts. Surface bypass alternatives described include concepts spanning the entire powerhouse as well as alternatives located at the north end of the powerhouse. Some concepts include de-watering facilities. The objectives of the report are to 1) describe surface bypass concepts; 2) estimate construction and operation and maintenance costs; 3) estimate time schedules for prototype development and construction; 4) evaluate advantages and disadvantages of each concept; and 5) recommend how to develop and test prototype systems.

Key Findings: No particular alternative was recommended due to limited data that was available for quantitative evaluations during the conceptual designs of the bypass systems. The report includes recommendations for hydraulic modeling at ERDC to evaluate hydraulic performance of alternatives and also suggestions for prototype development and biological testing

5. Montgomery Watson. 1998. John Day Surface Bypass Spillway. Feature Design Memorandum No. 52.

Organization: USACE Portland District
Project: John Day Dam
Type of Evaluation: Engineering design documentation of removable spillway weir.
Goals, Objectives, and Methods: The purpose of this Feature Design Memorandum (FDM) is to present biological rationale and criteria, spillway and gate designs, cost estimates, and a construction schedule for implementation of a surface bypass spillway at the north end of the John Day Powerhouse. The report identifies pertinent technical, operational, and maintenance factors, establishes specific design criteria, and develops a preliminary design for the structure. Two options are analyzed: three spillway chutes in each of Skeleton Units 19 and 20; and three spillway chutes in Skeleton Unit 20. The work consists of a hydraulic analysis and preliminary structural, mechanical, and electrical design of the spillway and its gates and bulkheads. Other work involves developing a gate alternatives analysis, cost estimate, construction schedule, cofferdam layout, and operation and maintenance considerations.
Key Findings: None.

D.3.2.2 John Day: Biological Evaluation

1. Anglea, S., T. Poe, and A. Giorgi. 2001. Synthesis of Radio Telemetry, Hydroacoustic, and Survival Studies of Juvenile Salmon at John Day Dam (1980-2000). Final report.

Organization: U.S. Army Corps of Engineers, Portland District
Project: John Day Dam
Type of Evaluation: Biological evaluation - review and synthesis
Goals, Objectives, and Methods: The goal of this report was to review and synthesize existing reports on research on downstream fish passage at John Day Dam. The objectives were to: 1) summarize fish behaviors including forebay approach patterns, residence times, and horizontal distribution of passage, 2) summarize fish passage and effectiveness data, 3) identify uncertainties and gaps in the data, and 4) provide recommendations to address the uncertainties. The authors reviewed 27 report on radio telemetry and hydroacoustic studies conducted between 1980 and 2000.
Key Findings: Radio telemetry studies indicated yearling Chinook salmon and steelhead approach the dam along the Washington side of the reservoir/forebay. Subyearling salmon approached along both shorelines. Some fish were observed delaying in the forebay, depending on time of arrival and dam operations. For example, daytime spill tended to reduce forebay residence times. Spill passage efficiency was variable, ranging from 52% in 1998 for juvenile steelhead to 77% in 1998 for subyearling Chinook salmon. The authors concluded (p. viii) that their review did "…not yield clear-cut results or relationships between fish passage and project operations."

2. BioSonics, Inc. 1999. Hydroacoustic Evaluation and Studies at The John Day Dam, 1997. Final Report. BioSonics, Inc., Seattle, Washington.

Organization: U.S. Army Corps of Engineers, Portland District
Project: John Day Dam
Type of Evaluation: Biological evaluation - fixed and mobile hydroacoustics and sonar tracker
Goals, Objectives, and Methods: In 1997, the Corps of Engineers installed stop logs in Spill Bays 18 and 19 to create prototype overflow weirs, i.e., surface spill SFOs. The weirs, however, allowed both overflow and underflow, so there were not true surface spill SFOs. Study objectives were to: 1) compare passage effectiveness for Spill Bays 18 and 19 with vs. without overflow weirs, 2) assess

spatial and temporal distributions in the forebay, and 3) estimate passage efficiencies and effectiveness values for each passage route (turbines, spill, overflow weirs). This hydroacoustic study occurred May 5-July 24, 1997.
Key Findings: In spring, overall averages for efficiency and effectiveness at Bays 18 and 19 were significantly higher during the weir “out” conditions than the weir “in” condition (P=0.06 and P=0.07, respectively). In summer, passage efficiency and effectiveness were similar between weirs in and out. The study results were likely affected by high volumes of spill elsewhere in the JDY spillway during this high-water year.

D.3.2.3 John Day: Physical Modeling

2. ENSR. 1997. Addendum to Final Report: Hydraulic Model Study of Spillway Fish Passage Over/Underflow Baffles for John Day Dam. Prepared for U.S. Army Corps of Engineers Portland District. ENSR document no. 09000-142-800.

Organization: USACE Portland District
Project: John Day Dam
Type of Evaluation: Physical model study
Goals, Objectives, and Methods: This report presents the results of additional model tests to finalize refinements to the prototype O/U baffle for field testing at John Day Dam during the 1998 migration season. Additional testing was necessary to refine the 1997 O/U baffle design and eliminate hydraulic phenomena considered unacceptable for fish passage. Specific refinements were made to eliminate separation along the baffle, create trapping velocities over the top of the baffle, and eliminate holding zones on the surface. Tests were performed for pool elevation 263 feet.
Key Findings: The 1998 refined 35/5 O/U baffle performance was satisfactory for flows between 5,000 cfs and 10,000 cfs. The 35/0 baffle did not meet minimum velocity criteria for flows less than 5,000 cfs. A 40/0 baffle was suggested to meet velocity criteria for flows less than 5,000 cfs and pool elevations between 261 feet and 262 feet. Model observations indicated that the O/U baffle could produce favorable conditions for fish passage at pool elevations other than 263 feet.

3. ENSR. 1997. Hydraulic Model Study of Spillway Fish Passage Over/Underflow Baffles for John Day Dam. Final Report. Prepared for U.S. Army Corps of Engineers Portland District. ENSR document no. 09000-137-600.

Organization: USACE Portland District
Project: John Day Dam
Type of Evaluation: Physical model study
Goals, Objectives, and Methods: This report documents the results of an hydraulic model study of the overflow/underflow (O/U) baffle in front of a spillway gate at John Day Dam. The Corps decided to conduct additional studies to refine the design of the The Dalles O/U baffle. The Dalles spillway model at ENSR was modified to represent the complete width of one spillbay at John Day Dam. Operational constraints and performance criteria are listed.
Key Findings: A refined O/U baffle is recommended for construction, but that the shape and orientation of the associated turning vane be investigated further. A table of acceptable range of operation for the unrefined and refined baffle configurations are presented.

D.3.3 The Dalles Annotated Reference List

D.3.3.1 The Dalles: Engineering Design

2. Harza and ENSR. 1996. Surface Bypass Alternatives at Bonneville, The Dalles, and John Day Spillways, Final Report, Vol. 1.

Organization: USACE Portland District

Project: Bonneville Dam, The Dalles Dam, John Day Dam
Type of Evaluation: Engineering evaluation of spillway bypass alternatives for Bonneville, the Dalles, and John Day Dams.
Goals, Objectives, and Methods: The objectives of this report were to 1) summarize the conceptual design and alternative selection process to date; 2) further develop four primary concepts for surface bypass at each of the three projects spillway dams; 3) develop conceptual level cost estimates and construction schedules; 4) discuss the advantages and disadvantages of the remaining bypass systems to enable future recommendations on how to proceed with the spillway systems; and 5) discuss prototype development options and hydraulic modeling needs to further advance any of the alternatives. Construction costs of modified spillbay alternatives were developed for each project, and system costs were defined based on the assumption that six spillbays would be modified.
Key Findings: Costs for each system ranged from about $8 million per project to modify six spillbays with overflow/underflow bulkheads upstream of the existing spillway gates, to about $56 million per project to retrofit surface gates and bypass channels to six spillbays. The selection of a preferred spillway system was not possible from the results.

4. HARZA, ENSR, and Fisheries Consultants. 1995. Surface Bypass Alternative Study at The Dalles Powerhouse- Final Report, Volumes 1-2.

Organization: USACE Portland District
Project: The Dalles Dam
Type of Evaluation: Engineering and biological evaluation of surface bypass alternatives at The Dalles powerhouse.
Goals, Objectives, and Methods: Alternatives for surface bypass of juvenile salmon at The Dalles powerhouse are described in this report. Three alternatives were selected by Corps and agency personnel based on their review of 30% and 65% submittals for surface bypass concepts. Surface bypass alternatives described include concepts spanning the entire powerhouse as well as alternatives using the existing sluiceway. Some concepts include de-watering facilities. The objectives of the report are to 1) describe surface bypass concepts; 2) estimate construction and operation and maintenance costs; 3) estimate time schedules for prototype development and construction; 4) evaluate advantages and disadvantages of each concept; and 5) recommend how to develop and test prototype systems.
Key Findings: No particular alternative was recommended due to limited data that was available for quantitative evaluations during the conceptual designs of the bypass systems. The report includes recommendations for hydraulic modeling at ERDC to evaluate hydraulic performance of alternatives and also suggestions for prototype development and biological testing.

5. U.S. Army Corps of Engineers. 2001. Design Documentation Report No. 32. The Dalles Lock and Dam Sluiceway Outfall With Auxiliary Adult Water. Volumes 1-5.

Organization: USACE Portland District
Project: The Dalles Dam
Type of Evaluation: Engineering and biological design documentation.
Goals, Objectives, and Methods: The report covers the design, construction, operation, and maintenance of the proposed Sluiceway Outfall Relocation with Auxiliary Adult Water Project at The Dalles Lock and Dam.
Key Findings: Following extensive modeling at ERDC and revised outfall flow and egress criteria, the proposed outfall site described in this report was unsatisfactory. Therefore, the report recommends that development of plans and specifications for the Outfall/Auxiliary Water Supply features not be completed until an alternate outfall site has been identified.

D.3.3.2 The Dalles: Biological Evaluation

1. Allen, B. and five co-authors. 2001. Monitoring Tailrace Egress in the Stilling Basin, the Ice-Trash Sluiceway, and the Powerhouse of The Dalles Dam, 2000. Annual report.

Organization: U. S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - radio telemetry
Goals, Objectives, and Methods: This study used radio telemetry to examine the movements and behavior of yearling and subyearling Chinook salmon in the tailrace of The Dalles Dam. The objectives were to describe: 1) movement patterns and residence times in the dam tailrace; 2) relationships between routes of travel through the tailrace and residence time; 3) diel patterns in behavior; and 4) movements of drift buoys through the tailrace. During approximately 40% spill discharge, 882 radio-tagged yearling Chinook and 699 radio-tagged subyearling Chinook were released in the forebay April 30-May 27 and June 20-July 18, respectively.
Key Findings: The overall detection rate was 91%. Tailrace residence time for fish passing through the powerhouse (156 min in spring and 372 min in summer) was double that for fish passing the north side of the spillway (85 min in spring and 102 min in summer). The tailrace residence times of sluice and south spillway fish were similar to those for the powerhouse. The release groups with the highest residence times tended to have southerly egress routes. The smallest residence times were for fish in the north spillway where tailrace water velocities are highest. During spring, 27 predation events were indicated by mobile tracking data. The majority of these events occurred upriver of the State Route 197 bridge and involved fish released south of Bay 7. Residence times for drogues and fish were similar. This study has bearing on siting the outfall for prospective SFO developments at TDA.

7. BioSonics, Inc. 1997. Hydroacoustic Evaluation and Studies at The Dalles Dam, Spring/Summer 1996. Volume 2 - Smolt Behavior. Final Report. BioSonics, Inc., Seattle, Washington to the Department of the Army, Portland District COE.

Organization: Department of the Army, Portland District COE
Project: The Dalles
Type of Evaluation: Review and synthesis
Goals, Objectives, and Methods: The intention of this study was to analyze salmon smolt behavior near The Dalles Dam during May, June, and July of 1996. This was done by actively tracking the fish with an acoustic transducer which automatically follows the fish, much like tracking radar, and records their positions and acoustic size. The seven degree circular split-beam tracking transducer was positioned about 10 meters below the surface. It was connected to a two-axis aiming armature which was moved by high-speed stepper motors. These motors were in turn controlled by the computer system which received the echosounder direction signals from the transducer in order to move the whole apparatus to keep the fish in the sonar beam for as long as possible.
Key Findings: This study produced many interesting plots which show continuous fish behavior. Some provide tracks of individual fish position or their velocity vectors, and even the average velocity vectors of fish in that area. These could be helpful in determining areas where flow and the smolts' reactions to the dam environment result in loss of fish and in guiding how such problems might be addressed.
The tracking transducer was most effective in deeper water. This was reflected in limited data gathered for fish moving above the bottom of the sluiceway intake. The problems with shallow water were a result of near-surface noise, and the author suggests the use of transducers with low sidelobes in future studies in order to reduce acoustic background noise. The report is also optimistic about the possibility of taking advantage of the high speed stepper motors allow predictive tracking of potentially more than one fish at a time.

8. BioSonics, Inc. 1999. Hydroacoustic Evaluation and Studies at The Dalles Dam, Spring/Summer 1998. Final Report.

Organization: Department of the Army: Portland District COE
Project: The Dalles
Type of Evaluation: Review and synthesis

Goals, Objectives, and Methods: The goal of this study was to examine the impact of two different spill levels on fish passage through the spillway at The Dalles Dam. The three major objective of this study were to estimate the effect of spill level on:

1. sluiceway passage efficiency and effectiveness.
2. spillway passage efficiency and effectiveness
3. the proportion of juvenile salmon passing through the turbines.

Flow was adjusted so that either 30% or 64% of the water would pass through the spillway, and fish passage was monitored through hydroacoustic techniques for comparison of the two spill levels. Transducers were deployed at 13 out of 23 spillways, all main turbine units, as well as all three sluiceway intakes above Main Unit 1. Each transducer was sampled for 2 minute periods every hour, used to calculate variances, and subsequently analyzed with a visual tracking program. Through the use of a weighting function it was possible to get hourly fish passage estimates for each sampled location.

Key Findings: The following table is based on one found on page 51 of the report:

Spring Outmigration						
Spill Level	Spillway	Turbine	Sluiceway	Total Passage	FPE	Effectiveness
30%	42.0%	8.4%	49.6%	2507651	91.6%	281.8%
64%	69.4%	4.9%	25.8%	2507651	95.1%	145.8%
Summer Outmigration						
Spill Level	Spillway	Turbine	Sluiceway	Total Passage	FPE	Effectiveness
30%	50.8%	10.4%	38.8%	1759060	89.6%	282.8%
64%	65.7%	8.0%	26.2%	1759060	92.0%	139.7%

There was no significant difference in fish passage efficiency (FPE) for 30% and 64% during the summer outmigration (according to a Wilcoxin signedrank test)., but there was significant difference during the spring, and fish passage effectiveness at 30% spill was far greater than at the higher spill rate.

9. Cash, K.M., D.M. Faber, T.W. Hatton, E.C. Jones, R.J. Magie, N.M. Swyers, R.K. Burns, M.D. Sholtis, S.A. Zimmerman, J.S. Hughes, T.L. Gilbride, N.S. Adams, and D.W. Rondorf. 2006. Three Dimensional Behavior and Passage of Juvenile Salmonids at The Dalles Dam, 2004. Final Report Submitted to U.S. Army Corps of Engineers, Portland District. Portland, OR. USGS.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - acoustic telemetry
Goals, Objectives, and Methods: The goal of this study was to provide information on fish movements in the forebay of The Dalles Dam to support siting and design of a potential behavioral guidance system (BGS). The purpose of a BGS would be to divert fish from the powerhouse over to the spillway operating at some level less than the currently mandated 40% of total project discharge during spring and summer. During 2004 and 2005, the Corps performed engineering studies for a BGS at TDA (see USACE 2006). The 3D acoustic telemetry study involved two arrays of hydrophones in the forebay, one in front of the powerhouse and one in front of the sluiceway. During April 29-July 26, 2004, the authors tagged (HTI acoustic transmitters) and released 366 juvenile hatchery steelhead, 357 yearling Chinook salmon, 74 juvenile sockeye salmon, and 364 subyearling Chinook salmon.
Key Findings: Tagged fish species showed similar migration pathways in the forebay. Overall, fish migrated downstream into the area known as Big Eddy, a relatively deep part of the thalweg upstream of the east end of the powerhouse. There, generally, the migration pathway splits into two paths, one toward the spillway and one toward the powerhouse. Approach paths were similar day vs. night. The authors concluded that a BGS off the east end of the powerhouse might successfully divert fish to the spillway.

12. Faber, D.M., M.E. Hanks, S.A. Zimmerman, J.R. Skalski, and P.W. Dillingham. 2005. The Distribution and Flux of Fish in the Forebay of The Dalles Dam in 2003. Final Report by PNNL Submitted to

the U.S. Army Corps of Engineers, Portland District. PNNL-14628.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - mobile hydroacoustics
Goals, Objectives, and Methods: In spring and summer 2003, mobile and fixed station hydroacoustic surveys were conducted in the forebay of The Dalles Dam to provide information on the distribution and movement of smolt-sized fish relative to flow, bathymetry, or diel cycle. This research supported an engineering planning and design effort for a behavioral guidance structure in the forebay at The Dalles Dam to divert fish from the powerhouse to the spillway.
The authors sampled the TDA forebay one day and night each week for six weeks in the spring and another six weeks in the summer. Two research vessels were used. Each pushed a raft outfitted with sampling gear consisting of two split-beam transducers, four single-beam transducers, one acoustic Doppler current profiler (ADCP), a pitch-roll-heading indicator, and a differential global positioning system (GPS). The split-beam transducers provided information on the location, size, and movement of fish. The ADCP sampled the flow environment in which each fish was detected. One 12° split-beam transducer was aimed downward. The other split-beam transducers and the four single-beam transducers were all forward-looking 6° beams that were aimed to provide intensive sampling in the upper 9 m of the water column. The rafts were secured 7.5 m forward of the bow of the research vessels (15 m from the vessel's outboard motor) to minimize fish avoidance behavior. Mobile sampling was conducted from a research vessel and raft moving in a zig-zag pattern extending from 180 m above the spillway to 1.8 km upstream of the spillway along 26 transects during each sampling period. A second research vessel sampled at 15 fixed-point locations for ten minutes at each point. From the fixed sampling we determined the rate and the direction of fish movement past those points (flux). Using the combined mobile and fixed sampling methods we were able to determine the distribution of smolt-sized fish and their movement patterns in the forebay. Smolt-sized fish were defined as those with a return signal of greater than -56 dB re??1µPa and less than -34 dB for spring fish (90-320 mm) or less than -45 dB for summer fish (90-105 mm). The species of smolt-sized fish that were targeted for springtime samples were juvenile steelhead trout (*Oncorhynchus mykiss*), juvenile yearling Chinook salmon (*O. tshawytscha*), juvenile coho salmon (*O. kisutch*), and juvenile sockeye salmon (*O. nerka*). Summertime samples were directed at subyearling Chinook salmon (*O. tshawytscha*).
Key Findings: In general, during the day in the spring, the greatest densities of smolt-sized fish were observed in the thalweg of the main channel from the Washington bank to the east side of the powerhouse, along the powerhouse, and in the areas adjacent to the sluiceway. The density of fish was relatively low on the Washington side of the river channel and west of the middle of the powerhouse (north spillway side). The spring night distribution was similar, with a few notable differences. The density of fish was higher on the east side of the powerhouse and along the face of the powerhouse, and more fish were detected on the north spillway side than during daytime. The distribution of sub-yearling-sized fish in summer followed the same general pattern as spring, except that summer fish had a greater presence on the east end of the powerhouse and on the north spillway area. Summer fish were not observed in densities comparable to those of spring fish near the sluiceway. Shad (*Alosa sapidissima*) populations in the summer may have also influenced the distribution maps generated during those periods.
The vertical distribution of fish was also determined. In spring, 80% of fish were above 5.6 m and 4.7 m of depth during the day and at night, respectively. The summer fish were similarly distributed in the day and night with 80% of the fish in the upper 4.5 m and 4.7 m of the water column respectively. In general smolt-sized fish were distributed deeper in the water column in the center of the channel than near the edges. Fish movement and distribution relative to physical conditions were also evaluated, but no strong associations were observed.
The net movement of smolt-sized fish in the forebay from fixed-point samples showed fish moving with the flow and channel upstream of the powerhouse but upstream at points near the powerhouse. The rate of fish movement (flux) was greatest at the east end of the powerhouse and on the upstream north side of the channel. The sample categories of fish distribution (spring/summer, day/night) shared key

findings:
•High densities of smolt-sized fish were observed on the north side of the channel.
•Shallow, high water velocity areas on the south side of the channel had relatively low densities of smolt-sized fish compared to adjacent regions. Larger than smolt-sized fish were distributed in these areas.
•The vertical distribution of fish was concentrated in the upper 5.3 m of the water column, regardless of time of day or season.
•Smolt-sized fish were deeper in the center of the channel than at the edges.
•The flux of fish was highest near the powerhouse and on the northeast side of the channel.
•Net movement of fish was downstream or with the channel in areas upstream of the powerhouse, but was less directed downstream in areas near the powerhouse.
•Findings for the sample categories, however, diverged on several accounts.
•In the spring, smolt-sized fish were distributed higher in the water column at night than during the day.
•Smolt-sized fish were distributed higher in the water column during summer than during spring.
•The density of smolt-sized fish was less during the summer than during the spring.
If a behavioral guidance structure is deemed to be a reasonable approach to juvenile salmon passage at The Dalles Dam, the authors made the following recommendations:
•Adjust powerhouse operation priorities so that the main flow encounters the guidance structure at a point nearest the spillway.
•Create flow parallel to the guidance structure, not perpendicular to it.
•Provide necessary attractant flow at the spillway.
•Build a structure with at least 6 m of depth.
•Consider surface flow bypass alternatives at the spillway and powerhouse.
Investigate further the relationship between bathymetry and fish distribution in the forebay in the shallow regions with high water velocities adjacent to the embankment at the east end of the powerhouse.

14. Hansel, H. S.D. Juhnke, P.V. Haner, L. Dingmon, and J.W. Beeman. 2005. Estimates of Fish, Spill and Sluiceway Passage Efficiencies of Radio-Tagged Juvenile Chinook Salmon During Spring and Summer at The Dalles Dam in 2004. Draft Final Report Prepared by USGS, Western Fisheries Research Center, Columbia River Research Laboratory for U.S. Army Corps of Engineers, Portland District.

Organization: U.S. Army COE, Portland District
Project: The Dalles
Goals, Objectives, and Methods: The objectives for this study were:
1. To estimate the proportion of radio-tagged fish passing through The Dalles Dam by way of the spillway, sluiceway, and turbines relative to their upriver horizontal location.
2. To determine the horizontal distribution of radio-tagged yearling and sub-yearling Chinook salmon upriver of the dam.
3. Obtain behavioral information on radio-tagged fish near the dam prior to passage.
4. Estimate sluiceway passage efficiency during two sluiceway operation scenarios.
5. Determine spill bay passage relative to the new spillway training wall.

The sluiceway operations test consisted of a randomized 2-day block design with two alternating 1-d treatments. The MU01 treatment consisted of opening up 3 sluiceway skimmer gates at MU01 at the west end of the powerhouse. The MU01+MU18 treatment meant opening an additional 3 skimmer gates at MU18 on the east end of the powerhouse. Each morning the treatment was changed. Fish passage data was collected using both underwater and aerial antennas, then proofed and analyzed using a SAS program.
Key Findings: The horizontal distribution of radio-tagged fish was much the same during day and night periods at upriver and downriver entrances. At the upriver entrance, 20% of the fish were located at the two southern locations and 80% were located at the two northern locations. At the downriver entrance, 57% of the fish passed the entrance at the north locations and 43% at the southern locations. SLPE was significantly higher during the MU01 treatment than the MU18+MU01 treatment. Overall estimates

of FPE, SPE, and SLPE were 84, 78, and 7%, respectively.

15. Hausmann, B., J. Beeman, H. Hansel, S. Juhnke, and P. Haner. 2004. Estimates of the Proportions of Radio Tagged Juvenile Salmonids Relative to Operation of the Sluiceway Guidance Improvement Device at The Dalles Dam in 2002. Final Report Prepared by USGS for U.S. Army Corps of Engineers, Portland District.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - radio telemetry
Goals, Objectives, and Methods: The goal of this study was to evaluate the turbine intake occlusion devices, also called J-occlusions. The objectives were to: 1) estimate proportions of radio-tagged fish passing via the sluiceway, spill, and total project separately for J-occlusions in and out; and 2) obtain data on fish behavior in the forebay. The researchers tagged and released 2,724 wild juvenile steelhead and 3,043 yearling Chinook salmon between May 2 and June 7, 2002. They also tagged and released 4,709 subyearling Chinook salmon between June 25 and July 13, 2002. The release sites were near or upstream of John Day Dam. Spill level during the study was 40% of total project discharge. Sluice gates 1-1, 1-2, and 1-3 were open.
Key Findings: Median travel times from JDY tailrace to the TDA forebay were 14-20 h. Forebay residence times at TDA were less than 0.5 h for all fish detected. The comparison of sluiceway passage efficiency for J-occlusions in vs. out produced mixed results, depending on species and day/night. The authors recommended (p. 75) deploying the J-occlusions in spring and removing them in summer.

16. Hausmann, B., Beeman, J.W., Hansel, H.C., Juhnke, S., and Haner, P. 2004. Estimates of fish, spill and sluiceway passage efficiencies of radio-tagged juvenile salmonids relative to operation of the Sluiceway Guidance Improvement Device in 2002. Report by U.S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory to the U.S. Army COE, Portland District.

Organization: U.S. Army COE, Portland District
Project: The Dalles
Type of Evaluation: Review and synthesis
Goals, Objectives, and Methods: In 2002, the USGS began a study to estimate the passage efficiencies of radio-tagged juvenile salmonids with respect to the Sluiceway Guidance Improvement Device at The Dalles Dam. SGIDs are steel plates designed to occlude the upper part of the turbine intakes. The objective for this study was to determine the proportion of radio-tagged steelhead juveniles and yearling Chinook salmon that passed through the powerhouse, sluiceway, and spillway in occluded and unoccluded treatments. They also intended to gather information on the behavior of the fish near the dam prior to passage. Both aerial and underwater antennas were used to detect fish.
Key Findings: The SGIDs increased steelhead spill passage of steelhead by 11%, although turbine passage was low with and without them. Non-turbine passage of radio-tagged fish was greater for juvenile steelhead than yearling Chinook salmon. There was no significant difference between FPE point estimates for juvenile steelhead during the day or night. The study indicated a statistically significant decrease in turbine entrainment of yearling Chinook salmon during the spring and sub-yearling Chinook during the summer. However, a hydroacoustic evaluation indicated a significant increase in entrainment. The authors' advice was to deploy the existing SGID's during the spring and place them in the unoccluded position during the summer.

17. Hedgepeth, J.B., G.E. Johnson, A.E. Giorgi, and J.R. Skalski. 2002. Sonar Tracker Evaluation of Fish Movements Relative to J-Occlusions at The Dalles Dam in 2001. Final report submitted to U.S. Army Corps of Engineers, Portland District.

Organization: U. S. Army Corps of Engineers, Portland District

Project: The Dalles Dam
Type of Evaluation: Biological evaluation -- active tracking sonar
Goals, Objectives, and Methods: The main objective of this study was to compare patterns of fish movement between conditions with and without turbine intake occlusions and J-extensions at The Dalles Dam. (The combination of intake occlusion and J-extension structures was termed a "J-occlusion.") Sampling occurred from April 24 to June 1, 2001. The J-occlusions were moved in and out of the water in 3-day increments according to a randomized block sampling design. Two active fish tracking sonars, commonly called sonar trackers, were deployed at Main Unit 1-2. One was mounted on the tip of the J-extension to sample fish movements when the J-occlusions were installed. The other was mounted about 20 m deep on a trashrack to sample fish movements when the J-occlusions were removed from the water. The primary area of interest for both trackers was a region 10 m wide, 15 m from the dam, and 10 m deep, immediately in front of Sluice 1-2. Over 2 million fish positions from about 46,000 fish tracks were obtained during the study. The study entailed three experimental factors: J-occlusions in/out, day/night, and spill/no spill (spill started on May 15).
Key Findings: In general, smolt movements were complex and multi-directional. Fish were not moving through the sample volume in a fixed, consistent direction. Overall, the trend regardless of treatment condition was westward (X-dimension; 56% west out of total west+east) and toward the dam (Y-dimension; 59% toward out of total toward+away). The proportion of fish moving upward in the water column was slightly higher with the J-occlusions in (Z-dimension; 52% up out of total up+down) than out (50%). The proportion of fish moving westward was about the same with (57%) and without (56%) J-occlusions. The proportion of fish moving toward the dam was the same (59%) whether the J-occlusions were in or out. Movements to the west, toward the dam, and upward were 3-5% stronger during day than night. The most dramatic effect on fish movements in front of Sluice 12, however, was caused by spill. When water was spilled, the proportion of fish moving westward toward the spillway was 63% compared to 49% during no spill. Also, movement proportions toward the dam and upward were 2-3% higher during spill than no spill. By definition, the zone of influence of the sluiceway was represented by probabilities greater than 0.9 from the Markov-Chain analysis of passage out the sluice side of the sample volume. The sluiceway zone of influence (mean day/night) was larger with the J-occlusions out (40 m3) than in (22 m3). The authors concluded the J-occlusions did not seem to have much effect on fish movements in front of Sluice 1-2, because the J-occlusions did not increase movement proportions up and toward the sluice entrance or enlarge the zone of influence at Sluice 1-2. This implies that if any benefits attend the J-occlusions, they may be associated with decreased turbine passage rates, which this study did not address.

19. Johnson, W.R., L. Johnson, and D.E. Weitkamp. 1987. Hydroacoustic Evaluation of the Spill Program for Fish Passage at The Dalles Dam in 1986. Report by Associate Fisheries Biologists, Inc. and Parametrix, Inc. to Portland District U.S. Army COE.

Organization: Portland District U.S. Army COE
Project: The Dalles
Goals, Objectives, and Methods: The primary goals set down for this project were to provide information on which to base regulation of spill, and to evaluate spill and sluiceway effectiveness in bypassing juvenile salmonids. In addition to these goals, they included a set of objectives they wished to accomplish:

1. Estimate the number of juvenile salmonids passing through the turbine units, spill bays, sluice gates, and the entire project on an hourly, daily, weekly, and seasonal basis.
2. Determine daily, weekly, and seasonal bypass effectiveness for both the spillway and the sluiceway.
3. Determine diel passage through the turbine units, sluiceway, and spillway for daily, weekly, and seasonal time periods.
4. Determine the horizontal distribution of fish through the turbine units, sluiceway, and spillway for weekly and seasonal time periods.
5. Provide in-season reports on an hourly, daily, and weekly basis as well as a final report with information about the four previous objectives, including daily discharge reports for each unit

(powerhouse, spillway, and sluiceway) as well as the total project. Examine vertical distribution at the turbines and spillway.

Data was collected using hydroacoustic equipment, including 21 15-degree transducers and two echo sounders. Eight turbine units were monitored, as were three sluice gates, and eight transducers were used for spill bay monitoring. Monitoring was performed 45 minutes per hour, 24 hours a day for 116 consecutive days, each transducer having been sampled at least twice each hour.

Key Findings: Sub-yearling Chinook often passed into the sluiceway in schools, suggesting that some of the estimates for times when schooling behavior was happening were probably underestimates. Even so, for the spring sampling period there were an estimated 1,116,970, 482,910, and 902, 983 migrants passed through the turbines, spillway, and sluiceway, respectively. The spring period 24-hour sluice effectiveness was estimated at 36%, and an effectiveness of 51, bypassing about 25 times the number of fish per unit of water when compared to the spillway. Some of the data suggests that smaller numbers of migrants make use of the sluiceway on days of larger spills. The depth of migrants in the water column was greater at night than during the day. They suggest that future studies focus on developing new schemes for transducer deployment in order to reduce trace type ambiguity.

20. Johnson, G., M. Hanks, J. Hedgepeth, B. McFadden, R. Moursund, R. Mueller, and J. Skalski. 2003. Hydroacoustic Evaluation of Turbine Intake J-Occlusions at The Dalles Dam in 2002. Final Report Submitted to the U. S. Army Corps of Engineers, Portland District, Portland, OR. PNWD-3226.

Organization: U. S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: This study evaluated the performance of turbine intake occlusion plates as a smolt protection measure at The Dalles Dam from April 20 to July 12, 2002. Prototype occlusion plates with J-extensions, hereafter called J-occlusions, were deployed at Main Units 1 through 4 (MU 1-4) and plates without J-extensions were deployed at the fish units just west of MU 1-4. The J-occlusions at MU 1-4 were moved in and out in a randomized block experimental design with 3-day treatments (IN or OUT). There were seven 6-day blocks in each of the 42-day spring and summer periods. Discharge at MU 1-5, the priority units at the powerhouse, was nearly equal between treatments. Total project discharge averaged 233 kcfs (36.9% spill) and 297 kcfs (37.4% spill) during the spring and summer periods, respectively. The three sluice gates at MU 1 were open nearly continuously during the study (total discharge ~ 4.5 kcfs). Smolt passage rates were estimated from fixed-location hydroacoustic samples collected at sluiceway entrances, turbine intakes, and the spillway. To analyze the data for a treatment effect, analyses of variance were performed separately for day and night periods in spring and summer. The three response variables were total turbine passage at MU 1-4, sluiceway efficiency (SLY1-4; proportion of sluice passage out of total turbine and sluice passage at MU 1-4), and total project fish passage efficiency (FPE; proportion of non-turbine passage out of total project passage).

Key Findings: The results of the J-occlusion analysis were mixed. In spring, there were no significant differences between the IN and OUT treatments for any of the response variables, except MU 1-4 passage at night (OUT > IN). In summer, the IN/OUT differences were usually significant, but the response variable means showed a negative J-occlusion effect. Therefore, it appears that the J-occlusions did not enhance smolt protection at The Dalles Dam in 2002. This result is consistent with results from occlusion plate tests at The Dalles Dam without J-extensions in 1995 and 1996, and with J-extensions in 2001.

Smolt movement patterns gleaned from the sonar trackers on the J-extension at the second intake of MU 4 and the pier nose between MU 4 and 5 revealed that fish movement in the sample region in front of MU 4 was predominately westward regardless of the presence of J-occlusions. A Markov analysis of movement patterns showed less westward movement and more damward movement with the J-occlusions IN than OUT in summer. Smolts 180 mm and larger were observed with the acoustic camera milling directly upstream of the trashracks of operating units. Therefore, smolt movement data

for the-run-at-large from the sonar tracker and acoustic camera corroborated the lack of a positive J-occlusion effect noted above for fish passage into turbine intakes beneath the J-occlusions.
Predator fishes at MU 1 and 2 were most likely to be found near the sluiceway entrance staging just below the sill or near the pier nose. At MU 3 and 4, predators were mostly observed roaming back and forth along the powerhouse near the intake trashracks with J-occlusions OUT or near the occlusion plates with J-occlusions IN. Predator abundance was similar between seasons and IN and OUT treatments. Thus, predators seemed to present in the forebay near the face of the dam irrespective of the J-occlusions.
The authors noted that, given mixed performance to date for turbine intake occlusion devices, cost should influence the decision about whether to proceed with a full complement of J-occlusions at The Dalles Dam.

21. Johnson, G. and seven co-authors. 2006. Hydroacoustic Evaluation of Juvenile Salmonid Passage at The Dalles Dam Sluiceway, 2005. Final Report Prepared for U.S. Army Corps of Engineers, Portland District. PNNL-15540.

Organization: U. S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: As in 2004, the goal of this study was to provide information on smolt passage that will inform decisions on long-term measures and operations to enhance sluiceway passage and reduce turbine passage to improve smolt survival at The Dalles Dam. The study objectives (see below) were met using a combination of hydroacoustic and hydraulic data. The study incorporated fixed-location hydroacoustic methods across the entire powerhouse, with especially intense sampling using multiple split-beam transducers at all sluiceway portals. The authors did not sample fish passage at the spillway in 2005. In the sluiceway near field, they used an acoustic camera to track fish movements. The fish data were interpreted with hydraulic data from a computational fluid dynamics (CFD) model. Fish passage data were collected in the framework of an “experiment” using a randomized block design (3-day treatments; two treatments) to compare two sluiceway operational configurations: Sluice 2+5 and Sluice 2+19 (six gates open for each configuration). The 90-day 2005 study was divided into two seasonal periods: spring (April 18 to June 4) and summer (June 5 to July 16).
Key Findings: The main findings, pertinent to SFO development and summarized by objective, were as follows:
Objective 1 -- Estimate fish passage run timing and vertical, horizontal, and diel fish distributions at the powerhouse.

- The vertical distribution of fish at the powerhouse turbine intakes was skewed toward the intake ceiling. Vertical distribution was deeper during summer than spring. Fish were deeper during night than day in spring, whereas the opposite was true for summer.
- At the powerhouse, the horizontal distribution showed fish passage was highest at Sluice (SL) 2 and Main Unit (MU) 8 during spring. During summer, passage at the powerhouse was highest at SL 2 and 5 and MU 8. The horizontal distribution of passage was not skewed to the east during summer, as observed in previous studies.
- Not including the sluice routes, fish passage per unit flow was highest at MU 21 during both seasons. Fish passage per unit flow in turbines was higher in summer than spring, and it was higher at the middle and eastern than western areas of the powerhouse in 2005.
- The diel distribution of passage was more variable during summer than spring. Generally, during spring and summer, passage at the powerhouse turbine intakes peaked at dusk while sluiceway passage was somewhat higher during day than night with no prominent peaks.

Objective 2 -- Estimate sluiceway passage efficiency and effectiveness (relative to total powerhouse passage) on a seasonal and daily basis.

- The following table shows the seasonal passage efficiency and effectiveness metrics with 95% confidence intervals at The Dalles Dam as estimated with hydroacoustics during 2005.

	Spring (4/18-6/4)	Summer (6/5-7/16)
Sluice Efficiency re: powerhouse	0.333 ± 0.14	0.217 ± 0.008
Sluice Effectiveness re: powerhouse	10.17 ± 0.43	5.72 ± 0.20

- Daily sluiceway efficiency and effectiveness estimates were variable with a decreasing trend from April to July.

Objective 3 -- Analyze the effect of sluiceway skimmer gate operation on fish passage into the sluiceway. Treatments included open sluice gates at Sluice 2+5 (SL 2-1, 2-2, 2-3, 5-1, 5-2, 5-3) and Sluice 2+19 (SL 2-1, 2-2, 2-3, 19-1, 19-2, 19-3).

- SL 2+5 had significantly higher sluiceway efficiency than SL 2+19 in both spring ($P<0.10$) and summer ($P<0.05$):
- For a given location, sluiceway efficiency was higher at SL 2 and SL 5 than SL 19 during both spring and summer (95% confidence intervals were within approximately 5% of the estimate).

Objective 4 -- Describe sluiceway near field fish movements and interpret these data using hydraulic data.

- The sluiceway zone of influence is the region immediately upstream of a sluice entrance where juvenile salmonids have a high probability (> 90%) of ultimately moving into the sluiceway. Data from the tracking effort using the acoustic camera in the sluiceway near field showed the zone of influence was highest at 17 ft during spring, night at SL 2.
- Generally, fish movement probabilities into the sluice entrances were higher during night than day and higher at SL 2 than SL 19.
- The predominate fish movement at SL 2 and SL 19 was to the west, not into the sluiceway, except for spring, night at SL 2.

The authors provided similar recommendations as Johnson et al. (2005) for SFO development at TDA.

22. Johnson, G.E., J.B. Hedgepeth, J.R. Skalski, and A.E. Giorgi. 2004. A Markov Chain Analysis of Fish Movement to Determine Entrainment Zones. Fisheries Research. pp. 349-358.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation -- statistical analysis and active tracking sonar
Goals, Objectives, and Methods: Fish can become entrained at water withdrawal locations such as fish bypasses or cooling water intakes. Accordingly, the size of a fish entrainment zone (FEZ) is often of interest to fisheries managers and facility operators. This study developed a new technique to map the FEZ, defined here as the region immediately upstream of a portal where the probability of fish movement toward the portal is greater than 90%. To map the FEZ, the authors applied a Markov Chain analysis to fish movement data collected with an active tracking sonar. This device locks onto and follows a target, recording positions through a set of volumetric cells comprising the sampled volume. The probability of a fish moving from one cell to another was calculated from fish position data, which was used to populate a Markov transition matrix. They developed and applied the technique using data on salmon smolts migrating near the ice/trash sluiceway at The Dalles Dam on the Columbia River.
Key Findings: The FEZ of the sluiceway entrance in 2000, as determined with this procedure, was approximately 5 m across and extended 6-8 m out from the face of the dam in the surface layer 2-3 m deep. Using a Markov chain analysis of fish track data, the authors were able to describe and quantify the FEZ of the sluiceway at The Dalles Dam. Such a Markov Chain analysis could be used in a comparative before/after study to look at changes in fish entrainment zones caused by engineered structures. The technique appears to be generally applicable to bioengineering efforts aimed at protecting fish populations affected by water withdrawals.

23. Johnson, G.E., J.B. Hedgepeth, A.E. Giorgi, and J.R. Skalski. 2001. Evaluation of Smolt Movements Using an Active Fish Tracking Sonar at The Sluiceway Surface Bypass, The Dalles Dam, 2000. Final report submitted to the U.S. Army Corps of Engineers, Portland District. BioAnalysts, Inc., Battle Ground, WA.

Organization: U. S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation -- active tracking sonar
Goals, Objectives, and Methods: The goal of the study was to improve understanding of why the sluiceway is effective. The objectives in 2000 were to: (a) track smolt movements in the near field (<10 m) of the Sluice 1-1; (b) estimate state proportions, fish velocity streamtraces, and fate probabilities; and (c) assess specific SFB premises regarding smolt movements in the Sluice 1-1 near field. An active fish tracking sonar (AFTS) was used to sample smolt movements in the near field of Sluice 1-1. AFTS is based on the principle of tracking radar. Once a smolt is detected with the digital split-beam hydroacoustic system, two high-speed stepper motors align the axis of the transducer on the target. As the target moves, deviation of the target from the beam axis is calculated and used to re-aim the transducer, thereby tracking the target. For each ping the target is tracked, three-dimensional fish position data are recorded. AFTS provided high resolution (~5 cm), three-dimensional fish position data for the run-at-large.
Key Findings: About 100,000 smolts were tracked and about 5,000,000 positions located during the study from April 17 to July 7, 2000 at The Dalles Dam. Descriptive data on fish movements revealed that more X, Y, Z fish positions were collected during night than day, although more fish were tracked during day than night (average number of pings per tracked fish was 29 during day and 88 at night). Fish moved in positive and negative directions in each of the three dimensions of the coordinate system, but the trend over the entire sample volume (15 m wide, 10 m out from the dam, and 9 m deep) generally was westward, toward the dam, and downward in the water column. Velocity magnitudes were mostly 0.5 to 0.5 m/s.
State, streamtrace, and fate analyses of fish movements provided data to understand why the TDA sluiceway is effective. From these analyses, the authors made the following findings: (a) Holding was not observed at the sluice entrances, but was seen in front of the top portion of turbine intake entrances (we sampled the upper 4 m of the intake), and was especially prevalent at night off the west pier nose by the Main Unit (MU) 1-1 intake. (b) Smolt movement was complex and multi-directional in the near field of the Sluice 1-1 entrance. (c) A zone of entrainment or attraction revealed by the state data appeared to be relatively small (2-3 m from the dam), but this must be substantiated by analyzing water velocity and smolt movement data between the downstream edge of our sampling volume (1.5 m off the plane of the pier noses) and the sluice weir. (d) The zone of influence of the sluice flow net based on the fate data was about 6-8 m from the dam in the surface layer (0-2 m). And, (e) the probability of sluice passage was highest immediately upstream of the east side of the Sluice 1-1 entrance.
The SFO hypothesis tests using fish movement data from AFTS assessed the validity of two SFO premises, attraction and shallow preference. The attraction premise is that smolts are attracted to and actively seek certain hydraulic conditions associated with SFOs. The shallow preference premise is that smolts prefer shallow passage routes at dams, i.e., they prefer not to sound and are reluctant to pass through turbine intakes. The statistical analyses indicated support for the premises.
In summary, the sluiceway was an effective, non-turbine route for passing smolts at The Dalles Dam because, for the most part, the smolt population migrating through the powerhouse is surface-oriented, can be concentrated at the west end of the powerhouse, is possibly attracted to the sluice flow net, and is reluctant to sound, preferring a shallow passage route over a deep one. The authors recommend that research at the TDA sluiceway during J-occlusion evaluations address the following points: 1) Assess specific hypotheses about smolt movements, such as the zone of influence associated with the sluiceway will be larger with J-occlusions than without; the proportion of fish moving upward and toward the sluice entrances will be higher with J-occlusions than without; and the overall probability of passage into the sluiceway will be higher with J-occlusions than without. 2) Integrate observed smolt movement data with hydraulic data from a computational fluid dynamics model. 3) Test the effects on sluiceway

passage of surface illumination using existing lights at Sluice Gates 1-1, 1-2, and 1-3.

24. Johnson, G.E., M.E. Hanks, F. Khan, J.B. Hedgepeth, R.P. Mueller, C.L. Rakowski, M.C. Richmond, S.L. Sargeant, J.A. Serkowski, and J.R. Skalski. 2005. Hydroacoustic Evaluation of Juvenile Salmonid Passage at The Dalles Dam in 2004. Final report submitted to the Corps of Engineers, Portland District by PNNL, Richland, WA. PNNL-15180.

Organization: U. S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: The goal of this study was to provide information on smolt passage at The Dalles Dam that in order to inform decisions on long-term measures and operations to enhance sluiceway and spill passage and reduce turbine passage to improve smolt survival at the dam. The study addressed two of the main programs dedicated to improving juvenile salmonid survival at The Dalles Dam: Spillway Improvements and Surface Flow Bypass. The study objectives (see below) were met using a combination of hydroacoustic and hydraulic data. The study incorporated fixed-location hydroacoustic methods across the entire project, with especially intense sampling at the sluiceway and spillway using multiple split-beam transducers at selected locations. At the sluiceway near field, the authors used an acoustic camera to track fish. The fish data were interpreted and integrated with hydraulic data from a computational fluid dynamics (CFD) model and in-field acoustic Doppler current profiler (ADCP) measurements. Data were collected in the framework of an "experiment" to compare two sluiceway operations: West only (sluice [SL 1) vs. West+East (SL 1 + SL 18). The 2004 study was divided into two periods: spring (April 19 to June 5) and summer (June 6 to July 17).
Key Findings: The key findings, pertinent to SFO development and summarized by objective, were as follows:
Objective 1 -- Estimate spill passage efficiency and effectiveness, sluice passage efficiency and effectiveness, and fish passage efficiency on a seasonal and daily basis.

- Daily sluiceway effectiveness relative to the project as a whole ranged from 0 to 9.98. Sluiceway effectiveness relative to the powerhouse ranged from 0 to 23.93. Sluiceway effectiveness was variable from day to day with a declining trend during the total study period.

Objective 2 -- Estimate vertical, horizontal, and diel fish distributions at the powerhouse and spillway.

- The vertical distribution of fish at the powerhouse turbine intakes and the spillway was deeper during summer than spring. At the powerhouse intakes, fish were deeper during night than day in spring, whereas the opposite was true for summer. At the spillway, fish were deeper during day than night during both spring and summer.

Objective 3 -- Analyze the effect of sluiceway skimmer gate operation on fish passage into the sluiceway. Treatments will include open gates in the west only (MU 1-1, 1-2, 1-3) and in the west and east (MU 1-1, 1-2, 1-3, 18-1, 18-2, 18-3) regions of the powerhouse.

- Opening east end gates increased total sluice passage over that for the west gates alone. For the study as a whole, total sluice passage was 11% higher in spring and 65% higher in summer with the east gates (SL 18) open than with the west gates (SL 1) alone. For only times when the West+East treatment was in place, total sluice passage was 21% higher in spring and 221% higher in summer with the east gates (SL 18) open than with the west gates (SL 1) alone. The results, however, usually were not statistically significant.
- Opening the east end sluice contributed 4 percentage points of the total 44% sluice efficiency at the powerhouse in spring and 7 percentage points of the total 17% sluice efficiency (re: powerhouse) in summer. In both day and night periods in spring and summer, sluiceway efficiency (re: powerhouse) was significantly ($P<0.05$) higher with the West+East treatment than the West only treatment.
- Opening sluice gates at the east end of the dam (SL 18) reduced turbine passage at the eastern part of the dam (MU 17 to MU 22), but the results were not generally statistically significant ($P>0.10$). In 3 of 4 combinations of treatment and season for day/night separately, east turbine passage during the treatment with the east end sluice gates open (West+East) was lower than during the treatment with the east sluice gates closed (West).

- The horizontal distribution data indicated passage into the west sluice gates (SL1) generally was not lower during the West+East treatment than the West treatment. If such was the case, it would indicate that opening the east end gates would not be a benefit because the fish that went in the east sluiceway entrance may have used the west entrance.

Objective 4 -- Describe sluiceway near field fish movements and integrate those data and sluiceway passage data with hydraulic data.

- The sluiceway zone of influence is the region immediately upstream of a sluice entrance where juvenile salmonids have a high probability of ultimately moving into the sluiceway. Data from the tracking effort using the acoustic camera in the near field of SL 1-3 and SL 18-3 showed the zone of influence was about 20-25 ft.
- Smolts displayed positive rheotaxis in the near field of the sluiceway. We also often saw schools of juvenile salmonids, as opposed to individual fish, moving into the sluiceway entrances.
- In general, juvenile salmonid movement patterns did not differ appreciably between the two sluice entrances. Fish approached from the east and northeast, some moved toward and into the sluice entrance while others continued west.
- The location of the observed sluiceway zone of influence corresponded with the location of the sluiceway flow net.
- Hourly sluice efficiency (re: powerhouse) data did not reveal any adverse effects from power peaking as indicated by total hourly powerhouse discharge and the difference in total discharge between successive hours.
- The relationship between sluiceway fish passage efficiency and sluice discharge proportion was positive for the powerhouse as a whole and for the east end sluice, but it was negative for the west end sluice.

The authors provided the following recommendations for sluiceway operations and long-term measures to enhance sluiceway and spillway passage and reduce turbine passage.

- Open six rather than three sluice gates to take advantage of the maximum hydraulic capacity of the sluiceway.
- Operate sluice gates in one or more of the combinations of six gates.
- Operate the turbine units below open sluice gates as a standard fish operations procedure.

The following elements for surface flow bypasses should be considered during design of any sluiceway enhancements at The Dalles Dam: form an extensive surface flow bypass flow net (surface bypass discharge greater than ~7% of total project discharge); create a gradual increase in water velocity approaching the surface flow bypass (ideally, acceleration < 1 m/s per meter); make water velocities at an entrance high enough (> 3 m/s) to entrain the subject juvenile fishes; adapt the shape and orientation of the surface entrance(s) to fit site-specific features; and consider installing a forebay wall to increase fish availability to the surface flow bypass.

27. McFadden, B.D. 1990. Hydroacoustic Evaluation of Juvenile Salmonid Fish Passage at The Dalles Dam in Summer 1989. Final report by BioSonics, Inc. to the U.S. Army Corps of Engineers, Portland District.

Organization: U.S. Army Corps of Engineers, Portland District

Project: The Dalles

Type of Evaluation: Review and synthesis

Goals, Objectives, and Methods: This study’s objective was to use hydroacoustic methods to generate hourly estimates of the number of juvenile salmonids (specifically Chinook, sockeye, coho, and steelhead) passing through The Dalles Dam spillway. It also attempted to determine the horizontal, vertical, and temporal distributions of these smolts during their passage. Two transducers were placed downward facing in the centers of the upstream sides of spillbays 16 through 23. Echogram data was collected for eight hours each night on 72 nights, all but one consecutively. Fish passage for the spillway was estimated at the end of each hour based on formulas and techniques used in a previous USACE study. Vertical distribution was calculated as a function of ranged from the transducer.

Key Findings: Estimates based on acoustic observations place the highest smolt passage on 16 – 17 June, which happened to be during the time of highest discharge through the spillway and powerhouse.

Other high points of fish passage were on the night of the 24th of June and 17th of August. Nightly, fish passage typically increased during the first four hours of spill and then decreased during the rest of the spill period, with the highest number of fish passing through the spillway at 2100 h. For the season, most fish entered the spillway between 7 and 10 meters of the surface, tending to pass slightly deeper later in the season. Horizontal distribution was largely a product of dam operation, with spillbays 21 and 19 having the highest fish passage over the monitoring season as well as the highest discharge. The report suggests that future studies monitor both the spillway and the powerhouse.

28. Moursund, R.A., K.D. Ham, P.S. Tizler, R.P. Mueller, G.E. Johnson, J.B. Hedgepeth, and J.R. Skalski. 2002. Hydroacoustic Evaluation of Fish Passage at The Dalles Dam in 2001. Final report submitted to U. S. Army Corps of Engineers, Portland District.

Organization: U. S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: At The Dalles Dam in 2001, turbine intake occlusion plates with J-extensions (hereafter called “J-occlusions”) were installed to decrease turbine passage rates of downstream migrant salmon and steelhead. The premise behind the J-occlusions was that they would cause water to be drawn into the turbines from deeper in the water column than without them, thereby reducing entrainment of surface-oriented smolts. The main objective of this fixed-location hydroacoustic research on fish passage was to evaluate the performance of the partial powerhouse prototype J-occlusions placed at Main Units 1-5. Secondary objectives were to (a) estimate overall fish passage metrics, such as project-wide fish passage efficiency, spill efficiency, and sluiceway efficiency, (b) estimate passage rates between the gaps between adjacent J-occlusions, and (c) compare smolt movement patterns in the near field of Sluice 1-2 with and without J-occlusions. Hydroacoustic transducers were deployed to estimate passage rates at all possible routes for downstream migrants (turbines, spillway, and sluiceway). The study period was April 24 to July 15, 2001.
The original randomized-block experimental design of treatments with J-occlusions IN or OUT was not met because of variable operations at MU1-5 and mechanical difficulties with raising and lowering the J-occlusions. Accordingly, a focused analysis using graphical presentations to allow the complex operations to be visualized alongside passage rates was performed.
Key Findings: Because 2001 was such a low-water year (flows 45% of the 10-year average), spill was limited, occurring only from May 16 to June 17. More than one factor appeared to influence fish passage at the J-occlusion units. Spill appeared to strongly influence turbine passage during unoccluded treatments, suggesting to the authors that spill had the greatest influence on fish that would have passed by the unoccluded route. J-occlusions apparently decreased turbine passage in the absence of spill, but not during spill. Sluice passage and efficiency increased during occlusion treatments at night, but not during the day. Spill also influenced sluice passage more during unoccluded treatment. The evidence suggests that during the unoccluded treatments fish were more influenced by spill and that occlusion plates are most effective at night and in the absence of spill.
Overall, FPE was 83% in spring and 14% in summer. Sluiceway efficiency relative to the powerhouse was 53% in spring and 6% in summer. Relative to the entire project, sluiceway efficiency was 18% and 5% in spring and summer, respectively. Spillway efficiency was 65% in spring and 9% in summer. Gap loss was about 17 fish per hour, although expanded estimates represent a small proportion of total passage. Effects of the J-occlusions on smolt movements were evident as noticeable, distinct differences in movement patterns between the IN and OUT conditions. Mean fish velocities, movement proportions, and fate probabilities all demonstrated differences between J-occlusions IN and OUT. Generally, the J-occlusions appeared to cause fish in the near field of Sluice 1-2 to decrease westward movement, decrease movement toward the dam, and increase upward movement in the water column. The authors concluded fish passage at the turbines of the partial powerhouse prototype J-occlusions was influenced by multiple factors, in rank order of apparent influence: spill, occlusion, diel effects, and adjacent unit configuration. In addition, the data indicated that the J-occlusions only affected smolt movement and passage in a region relatively close to the occluded intakes. To minimize the influence

of extraneous factors, future studies should include provisions for block-loading the turbines associated with the J-occlusions and for addressing spill flow variability.

29. Nagy, W.T. and M.K. Shutters. 1995. Hydroacoustic Evaluation of Surface Collector Prototypes at The Dalles Dam, 1995. Draft. U.S. Army Corps of Engineers, Cascade Locks, Oregon.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - fixed hydroacoustics
Goals, Objectives, and Methods: The goal of this study was to examine fish passage at new, prototype surface collection structures at the sluiceway and spillway. At the sluiceway, two SFO concepts were tested. First, trash racks were blocked from about elevation 155 to 120 ft MSL at two turbine intakes below open sluice gates at MU 1. Second, a “surface skimmer” was retrofit on the dam, replacing in the upper two trash racks below twp sluice gates. The back of this steel box served as a trash rack blockage. The front had a vertical slot entrance (dimensions not apparent in the report). Flow into the skimmer was controlled by the sluice gates. At the spillway, two bays were retrofitted with vertical slot entrance structures upstream of the tainter gate. Each vertical slot was 16 ft wide and extended from the spill ogee to the surface. Fixed hydroacoustic techniques were used to 1) compare passage into sluices and turbine intakes 1-2 and 2-2 with and without trash rack blockages, 2) compare passage at sluice 1-2 with the vertical slot surface skimmer to 2-2 with and without blocked trash racks, and 3) compare spill passage at vertical slot spill bays with that at unmodified bays. Samples were collected in spring (May 10-25, 1995) and summer (June 8-July 14, 1995). The sluiceway surface skimmer test was conducted in summer 1995.
Key Findings: No significant differences in sluiceway efficiency (defined here as sluice passage divided sluice plus turbine passage for turbines below the open gates) were found between blocked and unblocked trash racks. The authors noted that this comparison was likely affected by differing acoustic detection probabilities between the different treatments because of differing velocity fields. Sluice efficiency for the skimmer at 1-2 (daily mean 53%) was lower than at the unmodified sluice entrance 2-2 (daily mean 77%). Any location effect, however, could not be accounted for in the analysis. The report was a draft and analyses apparently were never completed. For example, the report did not contain results of the comparison of passage rates at modified vs. unmodified spill bays, although the considerably large amount of spill at the unmodified bays than the modified bays would have made this comparison difficult. The vertical slot structures retrofit on TDA’s sluiceway and spillway were not deployed again.

30. Nichols, D.W. 1980. Development of Criteria for Operating the Trash Sluiceway at The Dalles Dam As a Bypass System for Juvenile Salmonids, 1979. Report Prepared for the U.S. Army Corps of Engineers, Portland District. Oregon Department of Fish and Wildlife.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - fyke net
Goals, Objectives, and Methods: This study continued research in 1977 and 1978. The goal of the 1979 study was to develop and evaluate the sluiceway as a non-turbine passage route at TDA. The objectives were to: 1) determine which gates at MU 1 and 2 to open to maximize fish collection efficiency; 2) determine if sluice operations could be reduced in some hours while maximizing daily collection rates; 3) determine if there are sufficient numbers of subyearling fish using the sluiceway in July and August to justify its operation then; and 4) determine if the sluice gate settings for maximum passage of yearlings also maximize passage for subyearlings. To estimate sluiceway passage rates, a fyke net was fished in the sluiceway channel for all or part of 90 days of the 130-day study from April 10 to August 17, 1979. Project operations data were not reported; however, sluice inflow was said to be ~5,000 cfs for four open gates.
Key Findings: There was no difference between average daily passage for three gates (1-1, 1-2, 1-3)

and six gates (1-1, 1-2, 1-3, 2-1, 2-2, 2-3). Passage rates were highest during daylight hours. The 24-h and 16-h sluices operations had similar daily passage rates, but the 12-h operation had lower daily passage rates. Appreciable numbers of subyearling fish (~1.3M) passed in sluice flow in July and August. Subyearling passage was higher with four gates at MU 17-18 open, as opposed to four gates at MU 1-2 or MU 21-22. The authors recommended operating sluice gates 1-1, 1-2, 1-3 during April 1-June 15 and gates 17-3, 18-1, 18-2 during June 16-August 15. They stated (p. 25), "The Corps should consider developing portable or fixed skimmers at other projects where there are not safe passage conditions for downstream migrants such as John Day Dam."

31. Nichols, D.W. 1979. Passage Efficiency and Mortality Studies of Downstream Migrant Salmonids Using The Dalles Ice Trash Sluiceway During 1978. Oregon Department of Fish and Wildlife.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - fyke net
Goals, Objectives, and Methods: The goal of the study was to maximize the collection efficiency of the sluiceway as a non-turbine passage route at TDA. The objectives were to: 1) compare west vs. middle vs. east gate openings, and 2) compare adjacent vs. spaced gate configurations. A fyke net was fished in the sluiceway channel at MU1. It had a 3.5 ft square opening and was 20 ft long. The net sampled 4-10% of the cross-sectional area. Net capture efficiency was determined by mark-recapture. Daily samples were collected during April 17-June 23 and July 21-August 8, 1978. Project operations data were not reported; however, sluice flow was said to be 3,750 cfs.
Key Findings: Highest sluiceway passage was through the west gates at MU 1 and 2. Adjacent gate configuration had higher sluice passage rates than a spaced setup. The data indicated that as flow into the sluiceway increased so did passage rates. There was no statistical analysis of the passage data. The author recommended 24 h/d operation of sluice gates 1-1, 1-2, 1-3 between April 1 and August 15 each year.

32. Nichols, D.W., F.R. Young, and C.O. Junge. 1978. Evaluation of The Dalles Dam Ice-Trash Sluiceway As a Downstream Migrant Bypass System During 1977. Report Submitted to CENWP, Portland, OR. ODFW.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - fyke net
Goals, Objectives, and Methods: The goal was to determine the number and percentage of juvenile salmonids using the sluiceway under normal operating criteria. The criteria were those established by Michimoto and Korn (1969). A fyke net was placed in the sluiceway channel to sample fish passage.
Key Findings: Large numbers of emigrants (> 60,000 on some days) were estimated to be using the sluiceway. Sluice passage rates were highly variable on hourly and daily scales. The authors concluded the normal gate settings were not optimum to collect juvenile salmonids.

33. Nichols, D.W. and B.H. Ransom. 1981. Development of The Dalles Dam Trash Sluiceway As a Downstream Migrant Bypass System, 1980. Oregon Department of Fish and Wildlife, Portland, Oregon.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - fyke net
Goals, Objectives, and Methods: This study continued ODFW research in 1977, 1978, and 1979. The goal of the 1980 study was to continue development and evaluation of the sluiceway as a non-turbine passage route at TDA. The objectives were to: 1) determine the relationship between flow and passage of juvenile salmonids at the sluiceway; 2) estimate sluice fish collection efficiency of yearling and subyearling fishes for various sluice flows; 3) determine which gates to open to maximize passage of

subyearlings; 4) determine the abundance and diel distribution of late migrating subyearlings; and 5) determine the capture efficiency of the sluiceway fish sampling device. A 20-ft long fyke net with a 3.5 ft square opening was used to sample fish in the sluiceway channel. Mark-recapture was used to estimate net capture efficiency. Sluice discharge rates were calculated from the cross-sectional area of the channel and water velocity measurements using a Price-type current meter mounted on the fyke frame. Overall project operations, however, were not reported. The study periods were April 12-August 29 and October 1-December 18, 1980.
Key Findings: Rating curves for sluice flow by number of open gates, forebay elevation, and end gate height are presented in Figure 6 (p. 11). Yearling salmonid passage increased as sluice inflow increased, although the authors noted that an outage at MU 1 may have affected the results. Subyearling passage in the sluiceway was over four times higher at 3,500 cfs inflow than 1,600 cfs. Overall bypass efficiency estimates were unreliable because of abnormal behavior of test fish. There was no significant difference in subyearling passage rates between open gates at 1-1, 1-2, 1-3 vs. 17-3, 18-1, 18-2. Over 400,000 juvenile shad passed in sluice flow during October and November.

34. Nichols, D.W. and B.H. Ransom. 1982. Development of The Dalles Dam Trash Sluiceway As a Downstream Migrant Bypass System, 1981. Draft. Oregon Department of Fish and Wildlife, Portland, Oregon.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - fyke net
Goals, Objectives, and Methods: This study continued ODFW research in 1977, 1978, 1979, and 1980. The goal of the 1981 study was to continue development and evaluation of the sluiceway as a non-turbine passage route at TDA. The objectives were to: 1) determine the relationship between flow and relative collection efficiency of yearling salmonids at the sluiceway; 2) determine optimum gate configurations for maximizing sluiceway fish passage; 3) determine overall sluiceway fish collection efficiency. As in previous studies, a 20-ft long fyke net with a 3.5 ft square opening was used to sample fish in the sluiceway channel. The authors also evaluated airlift and fish trap sampling devices. Overall project operations were not reported. The study period was April 26-August 8, 1981.
Key Findings: Yearling fish passage rates in the sluiceway increased about 14% for each 1,000 cfs of sluice inflow. This relationship was linear up to 3,600 cfs. Passage of yearling and subyearling fishes did not differ between split (1-1, 1-2, 18-1, 18-2) and adjacent (1-1, 1-2, 1-3) gate operations. Sluiceway passage for yearling salmonids was significantly greater for three adjacent gates (1-1, 1-2, 1-3) compared to two (1-1, 1-2) or four (1-1, 1-2, 1-3, 2-1) adjacent open gates. This study reported estimates of overall sluiceway efficiency (relative to the powerhouse with presumably no spill) of 24% for yearlings and 32% for subyearlings. As the last study in the 1977-1981 series, this study provides a useful synopsis of the collective sluiceway research in the late 1970s and early 1980s at TDA.

37. Ploskey, G., T. Poe, A. Giorgi, and G. Johnson. 2001. Synthesis of Radio Telemetry, Hydroacoustic, and Survival Studies of Juvenile Salmon at The Dalles Dam (1982-2000). Final Report.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Biological evaluation - review and synthesis
Goals, Objectives, and Methods: The goal of this report was to review and synthesize existing reports on research on downstream fish passage at The Dalles Dam. The objectives were to: 1) summarize fish behaviors including forebay approach patterns, residence times, and horizontal distribution of passage, 2) summarize fish passage and effectiveness data, 3) identify uncertainties and gaps in the data, and 4) provide recommendations to address the uncertainties. The authors reviewed 29 report on radio telemetry and hydroacoustic studies conducted between 1982 and 2000.
Key Findings: The data showed that yearling fish tended to migrate in the main channel, and sub-yearlings were somewhat shoreline oriented. Smolts usually encountered the dam first at the east end

of the powerhouse, which is oriented parallel to the river axis, unless there was a lot of spill in which case more fish encountered the northern spillway first. Forebay residence times were typically very short; fish passed the dam within fractions of an hour after entering the forebay. Horizontal distribution of passage at the powerhouse depended on dam operations, but when all units were operating, distributions were either relatively uniform or were skewed toward higher number units. Diel trends in passage depended on route spill and sluice passage were higher during the day than at night, whereas turbine passage was higher at night than during the day. Once past the dam, smolts often encountered high densities of predators (both birds and fish) in the tailrace especially along the Oregon shore islands. Egress from the northern spill area was much quicker than elsewhere. Spill efficiency ranged from about 60% at 30% spill to from 72% to 84% at 40% to 60% spill. Relative to the entire project, mean sluice efficiency averaged from 11% to 13% and ranged from 6% to 24%, but it accounted for a more substantial percentage of fish passing the powerhouse alone (e.g., 39% in spring and 24% in summer 1999). Overall, project FPE ranged from about 80% at 30% spill to about 90% at 40% to 60% spill. Survival rates in sluice, spill, and turbine in spring were about 92%, 96%, and 81% to 86%, respectively, and they were all lower than estimates for other projects in the Columbia River Basin. In summer, the average survival of sub-yearling Chinook salmon was 92% for the spillway, 93% for the sluiceway, and 84% for turbines. The authors provided specific recommendations for research to address data gaps and critical uncertainties.

38. Rakowski, C.L., Richmond, M.C., Serkowski, J.A., Johnson, G.E. 2006. Forebay computational fluid dynamics modeling for The Dalles Dam to support behavior guidance system siting studies. Report by PNNL to the U.S. Army COE.

Organization: U.S. Army COE
Project: The Dalles
Type of Evaluation: Review and synthesis
Goals, Objectives, and Methods: The Dalles Dam presently has no downstream migrant fish passage facilities, and its survival estimates are among the lowest in the Columbia River Basin. To best determine the placement and design of a behavioral guidance system (BGS) structure at the dam, the Army COE tapped PNNL to develop computational fluid dynamics (CFD) models of the river around the dam. The study's primary objective was to create a new numerical model for the forebay that included the up-to-date bathymetry, extended further upstream, and more accurately represented the powerhouse and spillway structures than previous models.
A bathymetric surface stereolithography developed for a previous study at The Dalles Dam was integrated with multiple field-surveyed data sets to create a single-valued bathymetric surface. A BGS is intended to be a curtain or wall from the surface to a depth sufficient to divert juvenile salmon high in the water column towards the spillway and away from the powerhouse. Several angles starting from upstream of the powerhouse and extended downstream at various angles were discussed based on the model.
Key Findings: The Dalles Dam forebay model developed by PNNL matched well the velocity data gathered on the river. It also matched observations made on the 1:80 physical model of the forebay. The methodology generally used to contour topographic data was found to be inaccurate when transect data is too widely spaced. The author calls for contouring methodologies to be revisited, and warns against changing the 1:80 general scale model without doing so.

D.3.3.3 The Dalles: Physical Modeling

1. ENSR. 1997. Hydraulic Model Study of Spillway Fish Passage Over/Underflow Bulkhead for the Dalles Dam. Prepared for USACE, Portland District. ENSR, Redmond, WA. ENSR document number 9000-089-300.

Organization: USACE Portland District
Project: The Dalles Dam

Type of Evaluation: Physical model study.
Goals, Objectives, and Methods: A 1:15 scale physical model at ENSR was used to develop and refine the design of the over/underflow bulkhead. A brief review of field tests performed on several bulkhead options is presented.
Key Findings: A recommended bulkhead is presented with associated operational constraints, such as maximum gate opening or bulkhead submergence.

D.3.3.4 The Dalles: Multidisciplinary

2. U.S. Army Corps of Engineers. 2005. The Dalles Juvenile Behavior Guidance System (BGS) Feasibility Report. U.S. Army Corp of Engineers, Walla Walla District, Washington.

Organization: USACE Portland District
Project: The Dalles Dam
Type of Evaluation: Feasibility report for a Behavioral Guidance Structure (BGS).
Goals, Objectives, and Methods: This report attempts to determine alternatives that could be used as a low cost prototype, as well as full-scale permanent use, for a BGS. Biological, hydraulic, structural, geotechnical, construction, and operations, components were considered. Cost estimates were also developed. The report does not involve detailed engineering analysis of any alternatives, but does involve preliminary analysis to determine if an alternative appears feasible. Based on assumptions of size and location, environmental and hydraulic loads were estimated.
Key Findings: Head differential across the BGS should be minimized to minimize forces acting on the structure and anchors. The report suggests that the numerical fish surrogate model may be a great value in determining the final design criteria for the BGS.

4. U.S. Army Corps of Engineers, Portland District. 2006. Design Documentation Report No. 34. The Dalles Lock and Dam Juvenile Behavioral Guidance System (BGS). 100% Review February 2006.

Organization: U.S. Army Corps of Engineers, Portland District
Project: The Dalles Dam
Type of Evaluation: Engineering study
Goals, Objectives, and Methods: This report covers the design, construction, operation, and maintenance of a proposed BGS for The Dalles dam forebay. The purpose of the BGS would be to divert juvenile salmonids from powerhouse turbines to the spillway at some spill level less than the currently mandated 40% of total river discharge April-August. The report describes the project setting, technical aspects of the BGS design, concerns regarding construction and O&M, and cost estimates.
Key Findings: The recommended design is a tethered concept where the floating wall is anchored to the river bottom. The alignment for the BGS was at an oblique angle to the powerhouse starting in the vicinity upstream of the adult fishway exit at the east end of the powerhouse and extending across the forebay. Physical and CFD modeling showed that maximum length was about 1000 ft. The estimated cost was about $55M. The Corps concluded that before the BGS can move forward to Plans and Specifications that a new site selection study will needed to address fish passage objectives and navigation concerns, assuming regional concurrence that a BGS at The Dalles Dam is justified.

D.3.4 Bonneville Annotated Reference List

D.3.4.1 Bonneville: Engineering Design

1. BioAnalysts, ENSR, and INCA. 2001. Bonneville Second Powerhouse Corner Collector Site Selection Study. Final Submittal.

Organization: USACE Portland District

Project: Bonneville Dam
Type of Evaluation: Comprehensive study to develop a final recommendation for location and preliminary outfall design for a high flow juvenile bypass outfall.
Goals, Objectives, and Methods: The purpose of this study was to identify, evaluate, and recommend a location and a preliminary design for a high flow outfall as part of a Bonneville 2nd powerhouse corner collector surface flow bypass system. A two-stage study approach included using a general 1:100 scale physical model of Bonneville Dam at ERDC in Vicksburg, MS, and a 1:30 scale outfall model at ENSR. The outfall location and outfall type were investigated separately in the first stage, and combined into a single evaluation in the second stage. The first stage involved four main studies: 1) a general tailrace investigation; 2) a preliminary study of potential tailrace locations for an outfall; 3) a precursory hydraulic analysis of possible conveyance channel designs; and 4) a preliminary study of outfall types. The second stage involved a more refined analysis, design, and evaluation of the locations and outfall types.
Key Findings: The F-tip site with the Mid-Level Cantilever type outfall was considered the optimum outfall range/type combination for the B2 tailrace. It was recommended to be carried forward to the design phase for ultimate construction.

3. ENSR, Harza, INCA, and Cornforth Consultants. 1989. Bonneville First Powerhouse Juvenile Fish Surface Bypass High Flow Dewatering Facility and Outfall Alternatives Study. Final report.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Engineering study on feasibility of creating large-scale dewatering, bypass, and outfall facilities for juvenile fish collection facilities at Bonneville First Powerhouse.
Goals, Objectives, and Methods: The goal of the study was to examine the feasibility for creating large-scale dewatering, bypass, and outfall facilities for juvenile fish collection systems at Bonneville First Powerhouse. The report compares four dewatering and four bypass and outfall alternatives using Bonneville First Powerhouse as an example, but the study focused on providing information with broad application for hydroelectric dams. The alternatives were compared on the basis of biological, operations and maintenance, and cost performance criteria. Fisheries and hydraulic design criteria were derived from National Marine Fisheries Service (NMFS) and a parallel Corps review study of traditional screening criteria. Structural, mechanical, electrical, and geotechnical design criteria were derived from accepted industry standards.
Key Findings: The highest rated dewatering schemes were the Conventional and High-Velocity Inclined Screens. The highest rated bypass channel and outfall type for low flow (<500 cfs) was a smooth or corrugated subcritical flow bypass channel and a cantilever type outfall. For intermediate flows (500 to 1,000 cfs) and steeper subcritical slopes, the outfall choice was either cantilever or spillway. The outfall channel would be either smooth or corrugated, depending on energy slope requirements. For high flows (>1,000 cfs), the spillway or cantilever outfalls were considered good choices, although at-grade outfalls should be considered. The channel type would depend on the energy slope considerations. Some additional biological research were recommended for some options. Key inputs to the process of developing the best dewatering/bypass channel/outfall system were design development and prototype studies to develop the configuration and flow requirements, as well as field and hydraulic model studies to determine the acceptable range of outfall locations. The report estimates that the entire process, from input of information to start of construction, will require a minimum of 3 to 4 years.

4. ENSR and INCA. 2000. Hydraulic Calculations Supporting Bonneville Surface Collection High Flow Outfall Guidelines Research, Contract No. DACW57-97-D-0003, INCA Engineers, Task Order No. 20, Modification Case No. 01.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Engineering estimates of hydraulic parameters of plunging high flow outfall jet.
Goals, Objectives, and Methods: The purpose of the calculations was to provide estimates for

hydraulic parameters to Pacific Northwest National Laboratory (PNNL) for design and operation of their high flow outfall guidelines research test facility. The calculations were based on cross section jet velocity data collected in a 1:30 scale physical hydraulic model at ENSR using an acoustic Doppler velocimeter. Three different outfall type structures were investigated: a vertical transition chute (VTC), a skimming structure, and a cantilever structure. Two different jet entry flow conditions were considered: skimming and plunging.
Key Findings: The maximum energy dissipation rate, deceleration rate, shear stress, and strain rate were calculated for each test. However, the accuracy of the results was limited by both experimental and calculation techniques, which made it difficult to contrast the different outfall types based on measured data and calculated parameters. Decisions on the most appropriate outfall type will require assessment on the basis of other criteria, not purely hydraulic parameter considerations.

5. Harza and ENSR. 1996. Bonneville First Powerhouse 1997 Prototype Surface Collector System. Letter Report.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Engineering detail of prototype surface collector system concept for Bonneville First Powerhouse.
Goals, Objectives, and Methods: The objectives of this report were to develop and summarize design criteria, preliminary prototype surface collector (PSC) design details, a construction cost estimate, and a construction schedule. A discussion of the decision making process in selecting the preferred module framing configuration and slot entrance type is presented.
Key Findings: The preferred PSC configuration was Module/Trashrack Alternative 2. It provided the best balance of hydraulic operation, fish guidance, operational concerns, and structural cost.

6. Harza and ENSR. 1996. Surface Bypass Alternative Study at Bonneville First Powerhouse, Volume 1. Final Report Prepared for U.S. Army Corps of Engineers, Portland District.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Documentation of conceptual design alternatives for a surface collection and bypass system at Bonneville First Powerhouse.
Goals, Objectives, and Methods: The report summarizes the development of conceptual alternatives for surface collection and bypass systems at the Bonneville First Powerhouse. The purpose of the overall program was to study, construct, and evaluate prototype surface collection and bypass systems to improve survival of migrating salmonids. The objectives of this study included developing up to ten 30% conceptual design alternatives (see Volume 2), five 65% conceptual design alternatives (see Volume 2), and up to three 95% conceptual design alternatives. Project cost estimates were prepared at a conceptual level for each alternative and included construction, planning, engineering and design, construction management, and operations and maintenance.
Key Findings: The three alternatives that were considered at a 95% level included a concept (Alternative A) which spans the entire powerhouse with deep entrance slots, a corner collector concept (Alternative B) located at the south and/or north end of the powerhouse, and a concept (Alternative C) with extended submerged bar screens in each turbine intake bay with a bypass channel near the forebay spanning the entire powerhouse. A list of variables and criteria were identified to aid in predicting the potential performance of a surface collection facility.

7. Harza and ENSR. 1996. Surface Bypass Alternative Study at Bonneville First Powerhouse: Volume 2. Final Report prepared for the U.S. Army Corps of Engineers, Portland District.

Organization: USACE Portland District
Project: Bonneville Dam

Type of Evaluation: Documentation of conceptual design alternatives for a surface collection and bypass system at Bonneville First Powerhouse.
Goals, Objectives, and Methods: See Volume 1.
Key Findings: This report presents the 30%, 65%, and 95% project review meeting reports and also the 30% and 65% Submittals.

9. Harza and ENSR. 1996. Surface Bypass Alternative Study at Bonneville Second Powerhouse. Final Report. Volume 2. U.S. Army Corps of Engineers, Portland, Oregon.

Organization: USACE Portland District
Project: Bonneville Dam, The Dalles Dam, John Day Dam
Type of Evaluation: Engineering evaluation of spillway bypass alternatives for Bonneville, The Dalles, and John Day Dams.
Goals, Objectives, and Methods: See Volume 1.
Key Findings: This report presents the correspondence and meeting records, ENSR letter report on the overflow/underflow baffle, 30% submittal of general concepts, and project data tables.

10. Harza and ENSR. 1996. Surface Bypass Alternatives at Bonneville, The Dalles, and John Day Spillways, Final Report, Vol. 1.

Organization: USACE Portland District
Project: Bonneville Dam, The Dalles Dam, John Day Dam
Type of Evaluation: Engineering evaluation of spillway bypass alternatives for Bonneville, The Dalles, and John Day Dams.
Goals, Objectives, and Methods: The objectives of this report were to 1) summarize the conceptual design and alternative selection process to date; 2) further develop four primary concepts for surface bypass at each of the three projects spillway dams; 3) develop conceptual level cost estimates and construction schedules; 4) discuss the advantages and disadvantages of the remaining bypass systems to enable future recommendations on how to proceed with the spillway systems; and 5) discuss prototype development options and hydraulic modeling needs to further advance any of the alternatives. Construction costs of modified spillbay alternatives were developed for each project, and system costs were defined based on the assumption that six spillbays would be modified.
Key Findings: Costs for each system ranged from about $8 million per project to modify six spillbays with overflow/underflow bulkheads upstream of the existing spillway gates, to about $56 million per project to retrofit surface gates and bypass channels to six spillbays. The selection of a preferred spillway system was not possible from the results.

11. Harza and ENSR. 1996. Surface Bypass Alternatives at Bonneville, The Dalles, and John Day Spillways, Final Report, Vol. 2.

Organization: USACE Portland District
Project: Bonneville Dam, The Dalles Dam, John Day Dam
Type of Evaluation: Engineering evaluation of spillway bypass alternatives for Bonneville, The Dalles, and John Day Dams.
Goals, Objectives, and Methods: See Volume 1.
Key Findings: This report presents the correspondence and meeting records, ENSR letter report on overflow/underflow baffle, 30% submittal of general concepts, and project data tables.

12. Harza and ENSR. 1995. Surface Bypass at the Bonneville Second Powerhouse- 95% Submittal- Alternatives Refinement and Prototype Development.

Organization: USACE Portland District

Project: Bonneville Dam
Type of Evaluation: Engineering summary of conceptual alternatives for surface collection and bypass systems at Bonneville Second Powerhouse.
Goals, Objectives, and Methods: This report documents the development of surface collection and bypass system conceptual alternatives for Bonneville Second Powerhouse. The development of conceptual alternatives included evaluation of up to ten 30% concepts, up to five 65% alternatives, and up to three 95% alternatives. Development of the 95% concepts included biological, hydraulic, and structural refinement of each alternative. More detailed layouts of each alternative are provided, from which construction cost estimates were prepared. Disadvantages and advantages of each alternative are listed. Model and prototype testing concepts were also developed.
Key Findings: Three alternatives (A, B, and C) are described in this report. Alternative A performed the best with respect to fish passage efficiency performance, but was clearly the most expensive to construct and operate. With additional hydraulic modeling and biological testing, Alternatives B and C could possibly perform as well for less cost. Concepts in the 65% submittal may perform better than or equal to the three concepts discussed in this report. No recommendation is made for a particular alternative or concept. It was recommended that the prototype development and testing program outlined in the report proceed.

13. U.S. Army Corps of Engineers. 2001. 90 Percent Design Documentation Report. Bonneville Second Powerhouse High Flow Outfall Bypass System. USACE Portland District, Portland, OR.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Engineering design documentation report.
Goals, Objectives, and Methods: This document presents the development of the High Flow Outfall Bypass System (Corner Collector) for the Bonneville Second Powerhouse. The report documents: biological and hydraulic criteria and design requirements for the system; summarizes the findings of various design alternatives; presents the recommended design; and is the basis for preparing plans and specifications. The tools used for design of the outfall include CFD modeling and physical hydraulic modeling.
Key Findings: None.

D.3.4.2 Bonneville: Biological Evaluation

1. BioSonics Inc. 1998. Hydroacoustic Evaluation and Studies at Bonneville Dam, Spring/Summer 1997 Volume 1 and 2. Contract Report to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Organization: Portland District U.S. Army COE
Project: Bonneville
Goals, Objectives, and Methods: In conducting a hydroacoustic study at Bonneville Dam in 1997 to support fish passage improvements, BioSonics established several objectives. The first of these was to estimate the number of juvenile salmon passing through the sluicechute at the second Powerhouse. They also wanted to assess the effects of sluicechute operation on submerged traveling screen (STS) guidance efficiency and the number of juvenile salmon entering intake 11A. In addition, the study would also encompass an evaluation of different types of transducer mounts and mount points to best estimate juvenile fish passage through the spillway. All of the prior objectives were addressed with fixed position hydroacoustics, but mobile hydroacoustic techniques were employed for the final objective; to determine the spatial and temporal distribution of juvenile salmon in the forebay of Bonneville Dam, by day and by night, and by sluicechute operation.
Key Findings: Fish Guidance Efficiency (FGE) estimates at Unit 11A were very low through both study periods. The spring FGE was 5.0% with the sluicechute closed and 2.5% with it open, while during the summer the FGE was 2.8% when closed and 2.2% open. During the spring, Sluicechute Guidance

Efficiency (SGE) was 11.0% relative to passage through Unit 11A with the sluicechute open to the 61' elevation. At 68' gate elevation, the estimated SGE was 34.3%. Summer yielded an SGE of 20.3%. During the summer a piernose mount at Spillbay #5 estimated three times the number of fish that the same mount estimated in spring, supposedly due to milling behavior of fish, primarily adult shad. The mobile acoustic surveys showed fish densities higher in the summer than the spring and fish tending to concentrate near the powerhouses. Most fish were in the upper 15m of the water column. Daytime fish densities were significantly higher with the gate closed, a phenomenon not seen in the 1996 study at Bonneville.

2. Evans, S., L. Wright, R. Reagan, N. Adams, and D. Rondorf. 2005. Passage Behavior of Radio-Tagged Subyearling Chinook Salmon at Bonneville Dam, 2004. Draft Annual Report Submitted to CENWP, Portland, OR. USGS.

Organization: U.S. Army Corps of Engineers, Portland District
Project: Bonneville Dam
Type of Evaluation: Biological evaluation **-** radio telemetry
Goals, Objectives, and Methods: The goal of this radio telemetry study was to evaluate passage of subyearling Chinook salmon through all routes at Bonneville Dam. Objectives specific to the B1 sluiceway and B2CC were to estimate fish passage efficiency and effectiveness for the sluiceway and corner collector. During June 18-July 27, 2004, the authors tagged and released 11,683 subyearling Chinook salmon upstream of Bonneville Dam at John Day and The Dalles dams. Companion studies were performed by Ploskey et al. (2005) and Reagan et al. (2005).
Key Findings: Of total project passage for radio-tagged subyearling Chinook salmon, B2 passed the 60%, the spillway 35%, and B1 5%. Of the tagged fish determined to have passed at B1, 47% used the sluiceway. Of the tagged fish determined to have passed at B2, 33% used the B2CC. B2CC effectiveness (B2CC efficiency for the total project divided by the proportion of total project discharge at B2 that went through the corner collector) for subyearling Chinook salmon was 9.1, whereas effectiveness was 0.8 at the spillway. The authors concluded (p. ix) that "…project FPE of nearly 80% can be attained for subyearling Chinook salmon under a BIOP spill condition in conjunction with the operation of the B2 corner collector."

9. Faber, D.M., M.A. Weiland, R.A. Moursund, T.J. Carlson, N. Adams, and D. Rhondorf. 2001. Evaluation of the Fish Passage Effectiveness of the Bonneville I Prototype Surface Collector Using Three-Dimensional Ultrasonic Fish Tracking. Contract DE-AC06-76RLO1830 Related Services, Pacific Northwest National Laboratory, Richland, Washington.

Organization: U.S. Army Corps of Engineers, Portland District
Project: Bonneville
Goals, Objectives, and Methods: This study used 3D acoustic telemetry and Computational Fluid Dynamics (CFD) to evaluate the response of yearling Chinook and juvenile steelhead to the Prototype Surface Collector (PSC) at Powerhouse I of Bonneville Dam. Its goal was to use data from ultrasonic micro-transmitters implanted in fish to observe three-dimensional behavior of fish within 100 meters of the surface flow bypass structure in order to test hypotheses about migrant response to flow stimuli generated by the PSC.
Key Findings: Fish tended to follow the main flow of the river on their approach of the dam, usually first encountering the dam and PSC at Units 4 through 6 at Powerhouse I. Half of these fish actually passed the dam at Turbine Units 5 and 6, and the other half passed at southern Turbine Units 1 and 2. Steelhead were found to be twice as likely to mill in the forebay for more than 4 hours during the day as during the night, while Chinook were equally likely to mill, day or night. Chinook were twice as likely to directly pass through the dam at night as during the day, but Steelhead were 10 times more likely to direct pass. Integration of 3D behavior observations with the output of a CFD model developed by PNNL showed that migrants followed flows greater than ~3.0 ft/s (~ 0.9 m/s), and their behavior was

less directed in flows of lower velocity.

18. Johnson, G. and T. Carlson. 2001. Monitoring and Evaluation of the Prototype Surface Collector at Bonneville First Powerhouse in 2000: Synthesis of Results. Final report.

Organization: U. S. Army Corps of Engineers, Portland District
Project: Bonneville First Powerhouse
Type of Evaluation: Review and synthesis
Goals, Objectives, and Methods: The goal of this report was to consolidate results from studies at the B1 Prototype Surface Collector (PSC) in 2000. The objectives were to: 1) review results from the 2000 research, 2) relate 2000 results to previous findings (1998 and 1999), and 3) make conclusions about PSC performance in terms of collection efficiency by species and for the run-at-large. During 2000, a major research effort was undertaken involving radio telemetry, acoustic telemetry, fixed hydroacoustics, multi-beam acoustics, computational fluid dynamics modeling, and fish movement modeling.
The PSC was a prototype structure used to test whether or not fish would enter the vertical slot SFO entrances and at what fish collection efficiency. It extended across B1 Units 1-6 at the B1 powerhouse. It had six vertical slot entrances 20-ft wide and 40-46 ft deep depending on forebay elevation. Flow was set at 3,300 cfs for the 20-ft width. Fish passed into the PSC entrances and out the backside of the structure into the sluice or turbine intakes. The 2000 study was the definitive evaluation of the PSC of the 1998-2000 annual studies.
Key Findings:
1. Fish collection efficiency for the section of the powerhouse with the PSC (Units 1-6) was 82% for steelhead, 76% for yearling Chinook salmon, and 84% for subyearling Chinook salmon.
2. The PSC was twice as effective (percentage of fish divided by percentage of water) as spill at passing fish.
3. The PSC demonstrated proof of the SFO concept at B1.

19. Johnson, G.E. and A.E. Giorgi. 1999. Development of Surface Flow Bypasses at Bonneville Dam: A Synthesis of Data From 1995 to 1998 and a Draft M&E Plan for 2000. BioAnalysts, Inc., Vancouver, WA.

Organization: U.S. Army Corps of Engineers, Portland District
Project: Bonneville Dam, First and Second Powerhouses
Type of Evaluation: Review and synthesis
Goals, Objectives, and Methods: The objectives were to 1) summarize and integrate existing hydraulic and biological information; 2) identify critical information that is needed to advance surface bypass development; 3) identify surface bypass prototype configurations that could be evaluated in the near-term (2000-2001); 4) discuss the potential for effective surface bypass systems at B1 and B2; and 5) develop a draft monitoring and evaluation plan for 2000. This paper-study reviewed available publications and reports. It included B1 sluiceway work conducted in early 1970s and B2 sluice chute work in 1980s, but emphasized investigations of the B1 prototype surface collector and the B2 prototype corner collector during 1995-1998.
Key Findings: Baseline studies in 1995-1998 for surface bypass development at Bonneville Dam showed that:
- Smolt distribution in the channel upstream of Boat Rock influenced whether smolts migrated into B1, spillway, or B2 forebays.
- Residence time in the forebays was generally brief (< 1 h), which indicates smolts were actively migrating downstream and did not appreciably delay at the dam.
- Vertical distribution, while generally surface-oriented, was variable across seasons and years.
- Horizontal distribution data revealed concentrations of smolts upstream of Units 4-6 and Units 7-10 at various times at B1 and upstream of Units 11-13 in the south eddy at B2.
- Diel passage data were variable among species. Generally, there was a trend toward higher night than day passage.

- Preliminary smolt injury/mortality data from the B1 and B2 sluice outfalls were encouraging, but further injury/mortality research is necessary to develop high flow B1 and B2 surface bypasses.
- Smolt egress in the tailrace was relatively fast in 1996 (6-13 km/h), a high flow year. Egress, however, will have to be monitored in future surface bypasses at Bonneville Dam.
- The baseline data from the surface bypass program at Bonneville Dam in 1995-1998 provide a foundation for development of prototype structures. The baseline biological data are broad in scope, comprehensive, and relatively well reported.

The authors concluded the collective information to date (1998) supported continued development of surface bypasses at Bonneville Dam. At B1, the 1998 results from the PSC at Units 3-6 were encouraging. At B2, existing data justify development of the sluice chute as a corner collector surface bypass, although verification will be imperative. The B2 conveyance channel and outfall must be made more fish-friendly. The authors stated surface flow bypass seems to have the potential to increase smolt survival over that of existing systems at Bonneville Dam.

32. Michimoto, R.T. 1971. Bonneville and The Dalles Dams Ice-Trash Sluiceway Studies, 1971. U. S. Army Corps of Engineers, North Pacific Division, Fisheries-Engineering Research Program, Portland, Oregon, Report #20.

Organization: U.S. Army Corps of Engineers, Portland District
Project: Bonneville First Powerhouse and The Dalles Dam
Type of Evaluation: Biological evaluation - fyke nets at Bonneville and Biological evaluation - visual observations at The Dalles
Goals, Objectives, and Methods (Bonneville): The goal for this study was to evaluate operation of the ice-trash sluiceway as a non-turbine passage route at Bonneville First Powerhouse (B1). The objectives of this study were to 1) compare entry of fish into the sluiceway using overflow vs. underflow weir configurations, and 2) determine if submerged mercury-vapor lights increased fish collection at night. Overflow was obtained by lowering the entrance gates to elevation 70 ft MSL (2.5 ft depth). Underflow occurred when the lower leaf gate was raised 1 ft off the weir crest at elevation 68 ft MSL. Sluice gates at 4B, 4C, 6C, and 7A were opened. Mean sluiceway flows during tests were 688 and 1,028 cfs for underflow and overflow, respectively.
The author fished a 35-ft long fyke net in the sluiceway channel. The net opening was 7 x 7 ft. Average forebay elevation was 72.5 ft MSL during sampling episodes. Mercury-vapor lights (400-watt) were submerged 4 ft between open sluice gates. Samples were collected on eight weekend days between April 9 and June 12, 1971. The order of underflow and overflow was randomized, with one condition each day of a given weekend. One 1-h sample was collected at night on each of 16 sampling dates, except on the last two weekends when two daylight samples per day were collected. A total of 10 pairs of over/under data were obtained for each species (Chinook, coho, steelhead). The primary response variable was the logarithm of the ratio of overflow catch to underflow catch [R=log (over/under)].
Key Findings (Bonneville): Results for the entrance gate objective are presented in the following table derived from Figure 4 (p. 15). The ratio R was greater than 1 as follows:

Species	Night Samples	Day Samples
Chinook	2 of 8	2 of 2
Coho	4 of 8	1 of 2
Steelhead	5 of 8	2 of 2

Generally, for all three species, R increased as the spring season progressed. When coho salmon were predominant early in the season, they apparently preferred the underflow entrance. However, when steelhead trout were common later in the season, they apparently preferred the overflow entrance. Chinook salmon obviously preferred the overflow entrance during daylight samples when they were caught in appreciable numbers (701 fish) during the last two weekends of the study. The author recommended full-time operation of the B1 sluiceway gates 4B, 4C, 6C, and 7A from March 1 to June 30. A definitive conclusion about overflow vs. underflow sluice entrances could not be drawn from these data.

The lighting objective as compromised by deployment and equipment delivery complications. The author (p. 10) concluded that "lights did not aid collection of fish." He captured small numbers of fish in the B1 sluiceway at night with or without lights.

Goals, Objectives, and Methods (The Dalles): The study goal was to evaluate operation of the ice-trash sluiceway as a non-turbine passage route at The Dalles Dam. The objective of this study was to determine if there were operational problems associated with using the sluiceway to pass juvenile salmonids. Entrance gates were opened at 1-1, 1-2, 2-1, and 2-2 because previous sampling by NMFS showed gatewells at these locations contained more fish than gatewells elsewhere on the dam. The method was to visually examine flow fields at the entrances, in the channel, and at the outfall. Sluiceway passage data were not collected.

Key Findings (The Dalles): The author concluded that the flows looked acceptable for fish passage. He recommended opening sluice gates in spring to pass juvenile salmonids at TDA.

33. Michimoto, R.T. and L. Korn. 1969. A Study to Determine the Value of Using the Ice-Trash Sluiceway for Passing Downstream-Migrant Salmonids at Bonneville Dam. Final report.

Organization: U.S. Army Corps of Engineers, Portland District

Project: Bonneville First Powerhouse

Type of Evaluation: Biological evaluation - fyke nets

Goals, Objectives, and Methods: The goal for this 1969 study was to assess the feasibility of using the ice-trash sluiceway as a non-turbine passage route at Bonneville First Powerhouse (B1). The objectives were to: 1) estimate the number of downstream migrants entering the B1 sluiceway, and 2) determine the proportion passing into the sluiceway out of the total migrating through the B1 powerhouse. An objective to estimate survival rates could not be accomplished.

To sample sluiceway passage, the authors fished a fyke net in the sluiceway channel. The net was 35 ft long with an opening 7 x 7 ft. Samples were collected during daytime on six weekends in spring 1969. Four sluice gates were opened to create submerged inflow (also called underflow). Sluice flows ranged from 472 to 832 cfs. The authors released groups of batch marked hatchery fall Chinook salmon into the B1 forebay for the purpose of estimating the proportion passing into the sluiceway.

Key Findings: Juvenile salmonids used the sluiceway in appreciable numbers ("hundreds of thousands"). Fish entered the sluiceway mostly during daytime. The estimates of sluiceway collection efficiency, i.e., the proportion using the sluiceway out of total B1 passage, were unreliable. According to the authors, mortality for fish passing in the sluiceway was "negligible" and sluice passage conditions were more similar to spill than turbine. The authors recommended full-time operation of the B1 sluiceway in spring to protect juvenile salmonids from turbine passage. They also recommended that the Fisheries-Engineering Technical Advisory Committee consider operating sluiceways at other mainstem dams for the purpose of passing juvenile emigrants. The USACE agreed to operate the sluiceways at B1 and The Dalles dams for juvenile passage beginning in 1971.

36. Ploskey, G., P.N. Johnson, W.T. Nagy, C.R. Schilt, L.R. Lawrence, D.S. Patterson, J. Skalski. 1999. Hydroacoustic Evaluation of the Bonneville PH1 Prototype Surface Collection in 1999. Draft technical report.

Organization: U.S. Army Engineer District, Portland

Project: Bonneville

Goals, Objectives, and Methods: The goals established for this study were to test hydroacoustic sampling methods proposed for the year-2000 evaluation of the prototype surface collector (PSC), identifying potential biases or other problems, and to evaluate a split-beam deployment upstream of a PSC slot and compare its fish passage estimates to those of in-turbine transducers. The following specific objectives were set to facilitate the PSC performance evaluation:

1. Estimate passage of juvenile salmon through PSC Unit 5 during 2-day, 5- or 20-ft-wide slot treatments.
2. Estimate the numbers of juvenile salmon passing under the PSC unit during the two slot treatments.
3. Test for major differences in fish entering or passing the PSC dependent on the slot treatment each season.
4. Estimate fish passage efficiency (FPE), and test for differences among slot treatments.
5. Estimate PSC effectiveness (ratio of the proportion of fish collected to the proportion of water collected) and test for significant differences between treatments.
6. Use split-beam data to describe the distribution of observations of fish swimming velocity for fish within 2 meters of the slot at Unit 5.
7. Estimate PSC entrance efficiency, the number of fish detected by transducers with trajectories toward the opening divided by all fish detected.
8. Compare estimates based upon entrance sampling with split-beam transducers with estimates of collected fish based on in-turbine sampling.
9. Describe diel trends in fish passage, approach direction, and efficiency.

Key Findings: There was a significant correlation between in-turbine estimates of fish that had passed through the PSC with estimates of numbers passing into PSC, indicating that split-beam sampling in the forebay is a good method of estimating the number of collected fish. The PSC collected significantly more fish during 20-ft treatments than during 5-ft treatments, also having significantly higher entrance and slot efficiencies.

Passage of guided fish during the 5-ft treatment and unguided fish in general was higher at night, but guided fish passed more during the day during the 20-ft treatment, which is typical for surface passage at a sluiceway. 1999 estimates of PSC efficiency and effectiveness for Unit 5 declined from the estimates for units 3 and 5 in 1998. This was also observed for radio-tagged fish.

The authors make several recommendations. They suggest making the 20-ft PSC slot the primary focus of the next study because of its marked out-performance of the 5-ft slot. If sufficient resources are available, they advise sampling Units 1-6 in 200 by randomly locating a single down-looking transducer either on the right, center, or left part of the intake. If possible, one intake, preferably the one with the highest variance, could be sampled with two or more transducer to assess the spatial component of variance. An ultrasonic repulsion system for American shad is proposed to be installed upstream of the PSC unit to reduce bias in the summer estimate.

37. Ploskey, G., W. Nagy, L. Lawrence, D. Patterson, C. Schilt, P. Johnson, and J. Skalski. 2001. Hydroacoustic Evaluation of Juvenile Salmonid Passage through Experimental Routes at Bonneville Dam in 1998. Final Report. ERDC/EL TR-01-2.

Organization: U.S. Army Engineer District, Portland
Project: Bonneville
Goals, Objectives, and Methods: Fixed-aspect hydroacoustics were used to evaluate the passage of juvenile salmon, effectiveness and efficiency of several experimental routes at Bonneville Dam in 1998. The goals for this study were to assess the potential of a Prototype Surface Collector (PSC) with two deep slots to improve fish-passage efficiency (FPE), and to evaluate the potential of the sluice chute as a corner surface collector, possibly helping to improve FPE of juvenile salmon at Powerhouse 2. The PSC would operate in addition to a prototype extended submerged bar screen (ESBS) in Intake 8b and submerged traveling screens (STSs) in Units 1 and 2. The study also set out to identify any diel patterns in fish-passage metrics for all monitored routes. Open and closed sluice-chute treatments were done to estimate FPE of sluice chutes at Powerhouse 2, while tests were designed to determine if 5- and 20-ft-wide slot treatments altered fish-passage at the PSC.
Key Findings: The PSC was found to be both highly efficient and effective by both in-turbine and in-slot sampling, with efficiencies of greater than 80% for both spring and summer. 5-ft PSC slots were found to be twice as effective as 20-ft slots relative to flow. The efficiency of an ESBS declined significantly from spring through summer. The sluice chute at Powerhouse 2 was found to have great potential as a corner surface collector, with all metrics remaining high and relatively stable through summer, unlike the

FGE of Units 11-13, which declined significantly. The success of the sluice chute as a bypass may have partly been due to its location and the removal of turbine intake extensions (TIES) from Intakes 11-14. Most fish passed through the 13-ft-deep sluice chute during the day, but passage moved downwards at night when 40-ft deep slots passed significantly more fish.

38. Ploskey, G., M.A. Weiland, C.R. Schilt, P.N. Johnson, M.E. Hanks, D.S. Patterson, J.R. Skalski, and J. Hedgepath. 2005. Hydroacoustic Evaluation of Fish Passage at Bonneville Dam in 2004. Final Report Submitted to CENWP, Portland, Oregon. PNNL.

Organization: U.S. Army Corps of Engineers, Portland District
Project: Bonneville
Goals, Objectives, and Methods: This study marks the fourth year of comprehensive evaluation of the Bonneville Dam's many passage routes. Besides project-wide fish-passage efficiency (FPE) evaluations, this study looked at horizontal and vertical distributions of smolts, seasonal and diel changes in behavior and passage, and gap loss. A DIDSON, a high definition acoustic camera, was used to evaluate the approach of smolts and gather data on their swim paths as they approached the B2CC entrance in hopes of being able to qualitatively describe fish behavior, distribution, and likelihood of passage through B2CC. The project primarily used fixed-aspect hydroacoustics for data-gathering.
Key Findings: Species composition for the spring run was assessed by the Smolt Monitoring Facility at B2, and was found to be dominated by sub-yearling hatchery Chinook at 46% of total fish, followed by yearling Chinook at 30%. Coho salmon made up 19%, while steelhead had a weak run of 3%, and sockeye salmon made up about 2% of the total. The project FPE was 73.3 and 70.0% for spring and summer seasons, respectively. Percent spill was found to have a much greater impact on variations in FPE than spill rate. B1 sluiceway was particularly effective and passage estimates were very high, making it potentially helpful to attempt to increase its capacity. Data indicated that spilling over 150,000 cfs may result in diminishing returns.

39. Ploskey, G.R., C.R. Schilt, J. Kim, C.W. Escher, and J.R. Skalski. 2003. Hydroacoustic Evaluation of Fish Passage through Bonneville Dam in 2002. Final report submitted by Battelle to the U.S. Army Corps of Engineers, Portland District. PNNL-14356.*

Organization: U.S. Army Corps of Engineers, Portland District
Project: Bonneville
Goals, Objectives, and Methods: For the summer of 2002, PNNL was contracted for two studies. The goals for the first were to provide hourly estimates of fish passage and associated variances, as well as efficiency and effectiveness measures, for all operating turbine units, spillbays, and the two sluiceway entrances at Powerhouse 1. The second study was more focused on Powerhouse 2 (B2) turbines. It attempted to compare the fish guidance efficiency (FGE) at two modified turbine intakes with data from other B2 units from the first study, and to evaluate how many fish passed through screen gaps in B2 intakes compared to those which passed into gatewell slots. Both studies were in an effort to provide a third consecutive year of route-specific estimates of fish passage for the whole Bonneville project, and specifically to evaluate the effects of modifications to screens and gatewells on FGE.
The majority of data was gathered using hydroacoustic techniques, namely deployments of transducers for continuous sampling, but acoustic cameras were also used investigate some gap loss which was difficult to assess via hydroacoustics.
Key Findings: Unlike previous years, the Unit 8 extended submerged bar screen (ESBS) was as high during the summer as it was during spring sampling. Sluiceway Intake 7A was the most effective passage route the at Bonneville dam in 2002 by several times, suggesting that if the sluiceway channel can handle more discharge that the southern gates could be opened to provide additional surface-bypass flow. The data suggested that B2 FPE could be improved by up to 20% by shutting down the end units first at night. There was once again a southern skew to fish passage distribution at B2, implying that a new corner surface collector will be successful there. Spring project FPE was 79%, while it dropped slightly to 74% during the summer.

42. Ploskey, G.R., C.R. Schilt, M.E. Hanks, P.N. Johnson, J. Kim, J.S. Skalski, D.S. Patterson, W.T. Nagy, and L.R. Lawrence. 2002. Hydroacoustic Evaluation of Fish-Passage Efficiency at Bonneville Dam in 2001. Final Report. PNNL. PNNL-14047.

Organization: U.S. Army Corps of Engineers
Project: Bonneville
Goals, Objectives, and Methods: The goals which were set for this study were many. The authors set out to estimate the proportion of smolt-sized fish that pass Bonneville dam above and below in-turbine screens, through the spillway, and through sluiceway openings of more than a meter each season, as well as their vertical and horizontal distributions. Diel behavioral patterns were to be evaluated and described in the final report. They also hoped to determine average trajectories of salmon smolts and assess whether distribution upstream and downstream of the trash racks could explain why FGE decreases from spring to summer. Plans were developed to determine vertical distribution as fish approached the trash racks through three successive hydroacoustic samples. All data was gathered using hydroacoustic transducers, and processed using a computer automated tracking program and corrected downwards using sloped of regression to closely fit with results from human trackers.
Key Findings: Both spring and summer estimates for spill efficiency at Bonneville Dam were down about 30% from the year prior, probably due to lower spill volume resulting from the 2001 drought. Project-wide FPE was 63% during the spring and 53% during the summer. The fish passage effectiveness metric was much higher this year due to decreased flow. There was found to be a positive relationship between the number of hours of spill per day and FPE and spill-efficiency metrics, and more fish pass at night, leading the report to suggest at least 11 hours of night spill dill drought years. Fish passage through the southern half of the second powerhouse was high during both seasons. Powerhouse 2 fish passage estimates were generally higher in the late afternoon and at night.

44. Ploskey, G.R., L.R. Lawrence, P.N. Johnson, W.T. Nagy, and M.G. Burczynski. 1998. Hydroacoustic Evaluations of Juvenile Salmonid Passage at Bonneville Dam Including Surface-Collection Simulations. Final report for 1996. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi. EL-98-4.

Organization: U.S. Army Engineer District, Portland
Project: Bonneville
Type of Evaluation: Review and synthesis
Goals, Objectives, and Methods: The primary goals for this study were gather enough biological data in order to expedite the design and placement of a prototype surface-collector and to move closer to the estimation of fish passage efficiency (FPE) for the entire Bonneville project.
Four objectives were set for the project:

1. Make use of mobile hydroacoustic technology to measure horizontal and vertical distribution of salmon smolts in the forebays of both powerhouses and to characterize the diel variation in distribution in spring and summer.
2. During both spring and summer at Powerhouse 1 estimate smolt passage through two turbines and the center sluice gate above each and the FPE for the pair of turbines and sluice combined. There were two test conditions set for this objective; open versus closed sluice gates and blocked versus unblocked trash racks.
3. Investigate the swimming direction of salmon smolts just upstream of the two test units at Powerhouse 1, especially the area where flow splits between the turbines and the sluice gate.
4. Estimate the passage of guided and unguided smolts into eight turbine intakes of Powerhouse 2 and determine the effect that an open or closed sluice chute has on the FGE of adjacent turbine units.

Underwater cameras were also employed to help monitor smolts passing through sluice gates.
Key Findings: The mobile surveys place the mean densities of smolts relatively high and in mid-channel, while in summer they were more spread out along the face of the powerhouse. Smolts appear

to be rising up in the water column within 20 m of Powerhouse 1, a fact that could be well taken advantage of by a surface collector. However, there was a downward shift in vertical distribution within 30 m of Powerhouse 2. Lowering the zone of flow separation by blocking trash racks was found to be beneficial, greatly reducing turbine passage. Underwater cameras revealed that the lateral distribution of smolts as they pass into sluice 5B is skewed (two to one) towards the sides of the gates near concrete piers. Opening a center sluice gate increased the mean FPE of Unit 5 significantly by 35% in spring and 46% for Unit 3 in summer. Unit 3 in spring and Unit 5 in summer increased 18.6 and 10.1%, respectively. Sluice-gate treatments did not significantly effect the vertical movement of smolts, suggesting a limited range of influence on flow. Passage of juvenile salmon was higher in summer than spring, at Powerhouse 2 intakes than those at Powerhouse 1, and at night than during the day. Sluice-chute treatments did not reduce turbine passage. Average fish guidance efficiency was reduced from about 55 to 30% during summer. It would appear that either the smolt distribution changes within 10 m of the dam (closer than surveying got) or the smolts avoid screens as they enter intakes.

45. Ploskey, G.R., C.R. Schilt, M.E. Hanks, J.R. Skalski, W.T Nagy, P.N. Johnson, D.S. Patterson, J. Kim, L.R. Lawrence. 2000. Hydroacoustic Evaluation of a Prototype Surface Collector and In-Turbine Screens at Bonneville Dam First Powerhouse in 2000. DRAFT Report by PNNL, MEVATEC Corp., DynTel Corp., WES, USAE District, and the University of Washington to U.S. Army Engineer District, Portland.

Organization: U.S. Army Engineer District, Portland
Project: Bonneville
Goals, Objectives, and Methods: The primary goal of the this study at Bonneville Dam in the spring and summer of 2000 was to resolve critical uncertainties of surface collection at Powerhouse 1 by testing the efficiency of a new 6-unit Prototype Surface Collector (PSC) and to assess the implementation of extended length bar screens at Powerhouse 1. Specific objectives towards these goals were as follows:

- Estimate the number of fish entering the PSC above the above the floor elevation at all six PSC slot entrances and the number passing through the PSC based on in-turbine sampling at all 18 intakes of units 1-6.
- Estimate the number of juvenile salmon passing into the 18 intakes of units 1-6 under the PSC.
- Test for significant changes in the number of fish passing under and into the PSC among weeks each season.
- Estimate fish-passage efficiency and effectiveness for each of the PSC units and the entire PSC by week and by season.
- Compare the number of collected fish and FPE with hydroacoustic estimates of fish passage and guidance efficiency in units 7, 9, and 10 with submerged traveling screens and Unit 8 with an extended submerged bar screen (ESBS).
- Compare collected fish estimates based on in-turbine sampling with entrance sampling using split-beam transducers.
- Describe diel patterns of fish passage, effectiveness, and efficiency for each season and horizontal distribution of passage among the six PSC slots.
- Use fixed-aspect hydroacoustics to continuously sample the numbers of fish passing above and below an ESBS at Unit 8 and estimate fish passage and FGE for spring and summer.
- Compare hydroacoustic and netting estimates of FGE and fish passage in spring and summer.
- Estimate the vertical distributions of salmon immediately downstream of trash racks and upstream of the ESBS in spring and summer.
- Compare vertical distributions and smolt numbers and trajectories immediately downstream of trash racks with upstream sampling of the trash racks and FGE estimated by netting.

Key Findings: A major contributor to a modest 6% decline in FPE at Powerhouse 1, the PSC guided an estimated 18% of total fish passage in spring and 21% in summer. The PSC helped to make up for the decline of the FGE of in-turbine screens at Units 7-10 during the summer. Despite a relatively even horizontal distribution of flow, more fish passed through PSC units than through three of the four units north of the pier between Units 6 and 7. In-turbine sampling showed that the PSC performed as well as the ESBS did in spring and much better than both the ESBS and STS's during the summer.

48. Reagan, G., N. Adams, and D. Rondorf. 2005. Passage Behavior of Radio-Tagged Yearling Chinook Salmon at Bonneville Dam, 2004. Draft Annual Report Submitted to CENWP, Portland, OR. USGS.

Organization: U.S. Army Corps of Engineers, Portland District
Project: Bonneville Dam
Type of Evaluation: Biological evaluation - radio telemetry
Goals, Objectives, and Methods: The goal of this radio telemetry study was to evaluate passage of yearling Chinook salmon and steelhead through all routes at Bonneville Dam. Objectives specific to the B1 sluiceway and B2CC were to estimate fish passage efficiency and effectiveness for the sluiceway and corner collector. During April 27-June 2, 2004, the authors tagged and released 6,716 yearling Chinook salmon and 4,399 yearling steelhead upstream of Bonneville Dam at John Day and The Dalles dams. Companion studies were performed by Evans et al. (2005) and Ploskey et al. (2005).
Key Findings: Of total project passage, B2 passed the 59% of Chinook salmon and 66% of steelhead, the spillway 33% of Chinook salmon and 26 % of steelhead, and B1 8% of Chinook salmon and 8% of steelhead. Of the radio-tagged fish determined to have passed at B1, 53% of Chinook salmon and 55% of steelhead used the sluiceway. Of the radio-tagged fish determined to have passed at B2, 36% of Chinook salmon and 74% of steelhead used the B2CC. B2CC effectiveness (B2CC efficiency for the total project divided by the proportion of total project discharge at B2 that went through the corner collector) for Chinook salmon was 7.0 overall, 8.7 during the day, and 2.9 during the night. Steelhead had a B2CC effectiveness of 14.2 overall, 17.4 during the day, and 4.5 during the night. The authors concluded (p. ix) that reasonable total project fish passage efficiency "…can be attained if sufficient numbers of fish are passed via a combination of non-turbine routes (spill, sluice, turbine guidance systems, and the corner collector)."

55. Uremovich, B.L., S.P. Cramer, C.F. Willis, and C.O. Junge. 1982. Passage of Juvenile Salmonids Through the Ice-Trash Sluiceway and Squawfish Predation at Bonneville Dam, 1980. Annual Progress Report. Oregon Department of Fish and Wildlife.

Organization: U.S. Army Corps of Engineers, Portland District
Project: Bonneville First Powerhouse
Type of Evaluation: Biological evaluation - fyke nets
Goals, Objectives, and Methods: With the B2 powerhouse and its state-of-the-art intake screen juvenile salmonid bypass system scheduled to come online in 1982, it was anticipated that voluntary spill for fish protection would be curtailed, increasing the necessity for a viable non-turbine passage route at B1. According, the goal of the sluiceway component of this research was to determine operating criteria to maximize passage of juvenile salmonids through the B1 ice-trash sluiceway. The objectives were to: 1) estimate sluiceway fish collection efficiency for yearling salmonids; 2) determine the horizontal distribution of fish passing into turbines while the sluiceway is operating; and 3) determine the best sluice gate openings to pass subyearling Chinook salmon.
Fish passage in the sluiceway was sampled with a fyke net, 20 ft long with an opening 3.6 ft square. Net capture efficiency studies were conducted with marked fish released directly into the sluiceway. Sluiceway fish collection efficiency was estimated by releasing known numbers (6,000-12,000 per release) of marked fish (steelhead or coho) in the B1 forebay and recapturing them in the sluiceway channel. Horizontal distribution of turbine passage was estimated by dipping gatewells.
Key Findings: Fish collection efficiencies during spring with gates 4A, 4B, 4C, and 5A fully opened were not reliable because of the poor condition of the marked fish and abnormal diel and horizontal distributions of the test fish compared with wild fish captured during the study. Passage of wild salmonids through the B1 turbines was highest at Units 4-7 and 10. The authors noted that passage at

6B, 7A, and 10C, locations adjacent to walls, was especially high. Relative passage of subyearling Chinook salmon through "spaced" open gates 4B, 6B, 7A, and 10C was 68% higher than that for "adjacent" open gates 6A, 6B, and 6C. Criteria for optimum B1 sluiceway operations, however, remained to be defined.

56. Willis, C.F. 1982. Development and Evaluation of the Bonneville Dam First Powerhouse Sluiceway As a Juvenile Salmonid Bypass System. Final Summary Report Submitted to the U. S. Army Corps of Engineers and the National Marine Fisheries Service. Oregon Department of Fish and Wildlife.

Organization: U. S. Army Corps of Engineers, Portland District and National Marine Fisheries Service
Project: Bonneville First Powerhouse
Type of Evaluation: Review and synthesis
Goals, Objectives, and Methods: The goal of this study was to summarize findings from field research at the B1 sluiceway during 1979-1981, inclusive. Mark-recapture studies using fyke net(s) in the sluiceway channel were conducted. For details, see Michimoto and Uremovich (1980), Uremovich et al. (1982), and Willis and Uremovich (1982). Willis (1982) summarizes the work by these researchers to develop criteria to optimize operation of the B1 sluiceway as a juvenile salmonid bypass system.
Key Findings: For the B1 sluiceway, optimum operation was achieved with gates fully open 24 h/d at 4B, 6B, 7A, and 10C with forebay elevation at or above 74.5 ft MSL. Fish collection efficiency estimates for B1 as a whole were 83% for steelhead, 58% for yearling Chinook, 50% for coho, 42% for sockeye, 10% for wild subyearling Chinook, and 4% for hatchery subyearling Chinook. Confidence intervals for these estimates apparently were not computed.

58. Willis, C.F. and B.L. Uremovich. 1982. Evaluation of The Ice and Trash Sluiceway at Bonneville Dam As A Bypass System for Juvenile Salmonids, 1981. Annual progress report.

Organization: National Marine Fisheries Service
Project: Bonneville First Powerhouse
Type of Evaluation: Biological evaluation - fyke nets
Goals, Objectives, and Methods: This was a follow-on study to Uremovich et al. (1982). The study goal was to develop final criteria for B1 sluiceway operations that optimize sluiceway collection efficiency. The objectives were to: 1) determine the configuration and amount of flow for open sluice gates that maximize numbers of fish entering the sluiceway; 2) estimate fish collection efficiency for the sluiceway under the optimum configuration; and 3) determine factors other than discharge and location of open gates that influence sluice passage.
A new fyke net sampling apparatus consisting of a frame 6 x 6 ft with nine sections for fyke nets 2 x 2 ft was deployed in the B1 sluiceway channel at Unit 2B. Typically, the five nets in the corners and middle were fished. Mark-recapture was used to estimate net capture efficiency and sluiceway fish collection efficiency.
Key Findings:
1. Fish passage into the sluiceway at gates 6B and 7A was 6.1 and 3.7 times higher, respectively, for full flow (475 cfs) than half-flow (240 cfs).
2. Optimum fish passage was achieved by balancing flow into four open gates.
3. There was no difference in total sluice passage among the three combinations of four open gates that were tested (4B, 5B, 6B, 7A vs. 4B, 6B, 7A, 10A vs. 5B, 6B, 7A, 10A), except for yearling Chinook salmon during 4B, 6B, 7A, 10A. Consequently, this configuration was deemed the optimum one.
4. For yearlings, 82% of total 24-h passage was during daylight (0500-2100 h).
5. Sluiceway fish collection efficiencies were estimated to be 83% for steelhead, 58% for yearling Chinook salmon, 50% for coho, 42% for sockeye, 10% for wild subyearlings and 4% for hatchery subyearlings.

To maximize sluiceway collection efficiency, the authors concluded that forebay elevation should be kept at or above 74.5 ft MSL and turbine units under open sluice gates should be operated at full load.

D.3.4.4 Bonneville: Physical Modeling

1. ENSR and INCA. 2001. Bonneville Second Powerhouse Corner Collector Outfall, Model Study of Bottom Impact and Ambient Flow Sensitivity. Final Report. Prepared for U.S. Army Corps of Engineers Portland District. ENSR, Redmond, WA. ENSR document no. 3697-002-430.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Physical model study data collection of generic high flow outfall bottom impact and ambient flow sensitivity at Bonneville Dam.
Goals, Objectives, and Methods: The model study was performed to support research for high flow outfall guidelines. The objective was to determine the hydraulic conditions of the plunging jet when the outfall does not impact on the bottom. Pressures at the impact location and the outfall jet trajectory were measured. Velocity measurements across several jet cross sections were taken for varying ambient flow conditions.
Key Findings: The average impact velocity, converted from pressure measurements, exceeded 40 fps in only one test. However, instantaneous impact velocities were much larger than 40 fps. The probability of exceeding a certain impact velocity magnitude was reported for each test. The results also indicated that, for the range of flows expected in the tailrace of Bonneville 2nd powerhouse, changes in the ambient flow had no significant impact on the jet characteristics.

2. ENSR and INCA Engineers. 2002. Bonneville Second Powerhouse Corner Collector Outfall Final Design Documentation. Final Report. Prepared for U.S. Army Corps of Engineers Portland District. ENSR, Redmond, WA. ENSR document no. 03697-013-804.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Physical model study to document the hydraulic performance of the final outfall design and plunge pool using the 1:30 scale physical model at ENSR.
Goals, Objectives, and Methods: The specific objectives were to 1) measure bottom impact pressures along the centerline of the plunge pool; 2) measure the jet entrance cross-sectional area for each test; 3) measure the maximum jet entry velocity for each test; and 4) calculate shear stress and strain rates in the plunge pool. Jet entry velocity measurements were taken using a Nixon probe; bottom pressure measurements were taken using an array of pressure transducers; shear stresses and strain rates were calculated based on measured velocities and jet cross-sectional areas. The plunge pool flow pattern was also documented with video and photos. Data were collected for various outfall discharges, tailwater depths, and ambient flows, representing the extreme conditions expected during outfall operation.
Key Findings: The maximum value of shear stress was 0.022 pounds per square foot; the maximum strain rate was 400 feet per second per foot. The maximum bottom impact velocity was equal to 5.9 feet per second. An eddy on the left side of the plunge pool was noticed in two of the four tests.

3. ENSR and INCA Engineers. 2002. Bonneville Second Powerhouse Corner Collector Outfall. Final Report. Prepared for U.S. Army Corps of Engineers Portland District. ENSR, Redmond, WA. ENSR document no. 03697-013-430.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Physical model study of hydraulic conditions in a juvenile fish bypass outfall jet from both generic and existing (Bonneville 2nd powerhouse ice and trash sluice chute) outfall structures.
Goals, Objectives, and Methods: The main objective was to support the high flow outfall guideline research using the 1:30 scale physical model at ENSR, which had been constructed to study the design of the Bonneville 2nd powerhouse Corner Collector (B2CC) outfall. Specific objectives included: 1) conduct hydraulic investigations to predict the hydraulic conditions that may be encountered during field

tests; and 2) determine the hydraulic conditions required to prevent jet bottom impact. Data were collected for varying outfall discharges, invert elevations, and tailwater elevations. Two sensitivity tests of the jet characteristics at the existing B2 ice and trash sluice chute were also performed for various ambient flows.
Key Findings: Based on the bottom impact data, a predictive equation for bottom impact velocity was developed: V = 29.7 + 1.2d + 0.5 H 1.1D, where d is the outfall flow depth, H is the distance from outfall invert to tailwater elevation, and D is the tailwater depth. The jet characteristics for the existing ice and trash sluice chute outfall indicated bottom impact of various degrees. The results of the sensitivity tests of the existing B2 ice and trash sluice chute indicated that changes in the ambient flow had no significant impact of the jet characteristics.

4. ENSR and INCA Engineers. 2002. Bonneville Second Powerhouse Corner Collector Outfall Type and Site Selection Support Studies. Final Report. Prepared for U.S. Army Corps of Engineers Portland District. ENSR, Redmond, WA. ENSR document no. 03697-013-400.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Physical model study of hydraulic conditions in a juvenile fish bypass outfall jet and of resulting plunge pool requirements.
Goals, Objectives, and Methods: This model study investigated the characteristics of a plunging jet from a juvenile bypass outfall and the shape of the plunge pool required to control bottom impingement of the jet. Several different outfall designs were studied, including a cantilevered design that was also used for the plunge pool development. The jet characteristics were obtained by measuring velocity components at five cross sections along the trajectory of the jet, from which jet deceleration and energy dissipation could be estimated. The plunge pool was investigated first for a generic cantilevered outfall and ambient flow and then refined for a specific location in the B2 tailrace and a more detailed outfall design. The physical model floor was modified to incorporate a plunge pool filled with pea gravel.
Key Findings: The jet energy dissipation rates, estimated qualitatively based on the velocity profiles, were the highest for a cantilevered structure with a non-confined plunging jet and the lowest for a skimming jet. The final plunge pool was a 50 feet deep (below existing river bed), 345 feet long, and 165 feet wide design. Egress appeared to be efficient based on slug dye releases in the model and the maximum jet bottom impact velocity was 6.3 feet per second.

D.3.4.5 Bonneville: Multidisciplinary

1. BioAnalysts, ENSR, and INCA. 2000. Bonneville First Powerhouse High Flow Outfall Site Selection Study. Final submittal.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: High flow outfall site selection study
Goals, Objectives, and Methods: The goal of the study is to identify, evaluate in a preliminary manner, and recommend potential high flow (>1,000 cfs) outfall locations for the Bonneville First Powerhouse (B1 PH). The report focuses on the general tailrace investigation phase, which was to identify, evaluate, and recommend general areas downstream of both Bonneville powerhouses were high flow outfalls could be located. A modeling plan for the 1:100 scale general model at ERDC (formerly WES) was developed to assist in the identification and evaluation of the ranges and two trips to ERDC to witness outfall siting tests are documented in the report.
Key Findings: Potential outfall ranges were identified and the tailrace environment was characterized. The evaluation of the ranges was summarized in a matrix and included consideration of biological, hydraulic, structural, environmental, impact of operation, and cost factors. The intent of the report was not to select a final outfall location; rather the preliminary range evaluation was intended to be used as a starting point for a final selection and design process requiring further analyses using tools described in

the report.

2. CH2M Hill, Montgomery Watson, BioAnalysts, Inc., and Pacific Northwest Laboratory. 1998. Bonneville Dam Second Powerhouse Physical Guidance Device. Letter Report. U.S. Army Corps of Engineers, Portland, Oregon.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Engineering and biological evaluation of physical guidance device.
Goals, Objectives, and Methods: The scope of the report was to identify the information needed to move forward on physical guidance device (PGD) development and to outline an implementation program for developing that information. The starting point of the report is the work done for the existing Lower Granite Dam behavioral guidance system (BGS). The report also reviews biological considerations for developing the PGD as well as hydraulic modeling requirements, construction issues, schedule, and cost.
Key Findings: The report is not recommending a design concept, due to significant differences in the biological and hydraulic conditions between Lower Granite and B2 entrance channel and the lack of hydraulic modeling information. During the execution of the study, it was apparent that the 1:100 scale model at WES could not provide the level of hydraulic information needed. The authors conclude that the B2 PGD concept has sufficient merit to warrant continued investigation, for which new tools and acquisition of additional biological and physical information will be required. A recommended process to acquire the necessary information is outlined.

3. Harza Engineering Co., M.B. HDR, R2 Resource Consultants, BioAnalysts, and ENSR. 2001. Bonneville First Powerhouse Deep Slot Surface Collector Prototype Alternatives Study. Final submittal.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Engineering and biological evaluation of surface collector prototype alternatives.
Goals, Objectives, and Methods: The objective of this document is to develop an alternatives study which outlines, investigates, and develops various methods and options to proceed with development of a deep slot collection and bypass concept at Bonneville First Powerhouse (B1 PH). To meet the objectives, the study first describes an updated Alternative A from the Harza and ENSR 1996 study reflecting the most recent research and technology. A cost estimate and schedule was also developed. A list of “key unknowns”, associated with converting the existing B1 prototype surface collector into a permanent system was developed, which generated potential prototype designs that addressed those unknowns. The report presents three conceptual paths, representing different degrees of risk, funding, and time constraints, that could be followed to refine and ultimately construct a deep slot surface collection and bypass system at B1. Each path includes components of construction, hydraulic modeling, biological monitoring and evaluations, and laboratory and field testing. The three paths are evaluated using a comparison matrix, from which a final path is recommended for development of the updated Alternative A.
Key Findings: The recommended path is presented, which accomplishes the following: quick implementation, efficient collection and transport of juveniles that does not injure them, implementation based on earlier work and research, design and construction at a reasonable cost.

4. INCA Engineers, BioAnalysts, Chinook Engineering, ENSR, and R2 Resource Consultants. 1999. Bonneville 2[ND] Powerhouse Fish Guidance Efficiency Improvement Study. Final Report. Prepared for U.S. Army Corps of Engineers Portland District.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Biological and engineering study of potential prototype fish guidance improvements

at Bonneville Second Powerhouse (B2 PH).
Goals, Objectives, and Methods: The goals of this study were to: review past fish guidance efficiency research, analyses, and modifications; provide estimated costs and biological benefits of potential improvement alternatives; and provide estimated costs of prototype development and implementation for regional consideration prior to more detailed studies. The report compares B2 PH to other projects on the Columbia and Snake Rivers, and provides an analytical framework to synthesize behavioral and hydraulic information. The engineering components that could be designed and constructed are developed and the associated feasibility cost estimates presented. A decision process was developed that can be followed as additional biologic and hydraulic research data become available. A matrix of possible criteria and assessment of potential alternatives is presented.
Key Findings: After review and analysis of available biologic and hydraulic research, it was not possible to determine the reasons for poor fish guidance efficiency at B2 PH. Due to the lack of biological and hydraulic data, the authors considered it almost impossible to assess potential improvement in fish guidance efficiency as the result of implementing any alternative component. Development of an evaluation matrix was also considered very difficult due to lack of reliable data and disagreement among interested parties within the region on priorities and values. However, some recommendations were made including to implement a research program to collect additional biological, hydraulic, and prototype data.

5. INCA Engineers, FishPro, Northwest Hydraulic Consultants, R.W. Beck, AGRA Earth and Environmental, BioAnalysts, and Battelle Pacific Northwest Laboratories. 1997. Bonneville Second Powerhouse Prototype Corner Collector. Final Report. Prepared for U.S. Army Corps of Engineers Portland District.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Engineering and biological evaluation of a prototype corner collector surface flow bypass system.
Goals, Objectives, and Methods: The objective was to further investigate the design options and potential effectiveness of a prototype corner collector and bypass system, initially examined as Alternative B in the Bonneville Second Powerhouse Surface Collection Alternatives Study (Harza and ENSR 1996). This report describes the existing facilities, physical and operational constraints, and hydraulic characteristics of the existing ice and trash chute. The report also reviews the background and logic by which several design alternatives were developed, a more detailed engineering design of the proposed facilities, and discussion of design criteria. Cost estimates were developed for each design phase. Some preliminary physical modeling of forebay and tailrace velocities was completed at WES.
Key Findings: The report concludes that a corner collector located in the south corner of the Bonneville Second Powerhouse could potentially improve the fish passage efficiency for this project. The available research indicated that juveniles were presented in the general area of the south corner and may actually use the ice and trash chute when available. Preliminary modeling indicated that high flow volumes through the ice and trash chute entrance created an hydraulic flow pattern that will both bring the juveniles to the entrance and provide a clear alternative to the turbine intakes. A prototype test program is recommended using the ice and trash chute. The cost to modify the ice and trash chute to improve fish passage conditions was found to be relatively minor. A monitoring and evaluation program was recommended to provide additional research data.

6. U.S. Army Corps of Engineers. 1992. Bonneville Second Powerhouse Fish Guidance Efficiency Improvements. Design Memorandum 42. USACE, Portland District, Portland, OR.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Engineering description of improvements at Bonneville Second Powerhouse.
Goals, Objectives, and Methods: The report describes the fish guidance efficiency improvements,

presents a new whirly crane, plans for a new storage area for turbine intake extensions, modifies the approved trash cleaning procedures, and includes a schedule and cost estimate that completes fish-related construction at Bonneville Second Powerhouse
Key Findings: None.

7. U.S. Army Corps of Engineers, Portland District. 2002. Bonneville Decision Document Juvenile Fish Passage Recommendation.

Organization: USACE Portland District
Project: Bonneville Dam
Type of Evaluation: Engineering and biological evaluation of bypass alternatives.
Goals, Objectives, and Methods: The purpose of the document is to determine the appropriate measures that should be implemented to improve juvenile survival at Bonneville Dam. The goal was to determine the appropriate measures to be implemented, the relative priority of the measures, and operational issues such as powerhouse priority and appropriate level of voluntary spill to improve juvenile survival. A list of alternatives is presented and compared from perspectives of cost, schedule of implementation, survival estimates, and 2000 Biological Opinion (BIOP) performance standards. Survival estimates were made using SIMPAS, a spreadsheet model developed by NMFS and used in the 2000 Biological Opinion.
Key Findings: The outcome of the document were the following recommendations: 1) The Second Powerhouse (B2) will be the priority powerhouse; 2) Implement B2 Corner Collector as soon as possible; 3) Continue to evaluate methods to improve B2 fish guidance efficiency and implement if results are favorable; 4) Defer decision on B1 until critical information is available. Improvement is needed at B1 but it is unclear what the appropriate fix should be; 5) The performance standard for B1 as laid out in the 2000 BIOP will be deferred.

D.4 Other Pacific Northwest Rivers Annotated Reference List

D.4.1 Mayfield Reference List

D.4.1.2 Mayfield: Biological Evaluation

2. Smith, J.R., J.R. Pugh, and G.E. Monan. 1968. Horizontal and Vertical Distribution of Juvenile Salmonids in Upper Mayfield Reservoir, Washington. United States Fish and Wildlife Service, Washington, D.C. Special Scientific Report - Fisheries No. 566.

Organization: Bureau of Commercial Fisheries Biological Laboratory
Project: Mayfield Dam
Type of Evaluation: Biological evaluation - gill net and trawl
Goals, Objectives, and Methods: The objective of this study was to determine the horizontal and vertical distributions of juvenile salmonids in an upper reservoir location. The intent was to provide data for design of potential fish collection facilities in such an environment. Gill nets and a trawl were systematically sampled during this study from April 1964 to June 1965 in upper Mayfield reservoir on the Cowlitz River in southwest Washington.
Key Findings: Of all 11,467 juvenile salmonids captured during the study, 87% were taken in the upper 24 ft of the water column. These data support the SFO premise that juvenile salmonid are surface-oriented.

3. Thompson, J.S. and G.J. Paulik. 1967. An Evaluation of Louvers and Bypass Facilities for Guiding Seaward Migrant Salmonids Past Mayfield Dam in Western Washington. Prepared for the City of Tacoma, Tacoma, WA. State of Washington, Department of Fisheries, Research Division and the University of Washington.

Organization: City of Tacoma
Project: Mayfield Dam
Type of Evaluation: Biological evaluation **-** mark-recapture
Goals, Objectives, and Methods: The goal of this study was to understand the prototype SFO louver and bypass system at Mayfield Dam in 1964 and 1965. The objective was to estimate louver/bypass guidance efficiency under various conditions. Juvenile coho, Chinook, steelhead, and cutthroat were marked with tattoos or partial fin clips and released in Mayfield reservoir. They were recaptured in the SFO bypass sampler (guided) and in special louver nets (unguided). The key response variable was guidance efficiency (number guided divided by the total number guided and unguided). The SFO at Mayfield Dam is a forebay collector with V-shaped louvers guiding fish to a vertical slot entrance into a bypass system.
Key Findings: Average guidance efficiencies were 66% for coho, 81% for Chinook, and 79% for steelhead. Too few cutthroat were caught to make estimates. In general, the louvers seemed to effectively guide fish toward the bypass entrance. However, as the authors stated (p. 41), "…the bypasses [entrances] are too narrow for yearling fish and incorrect water velocities are evident in the critical area at the bypass entrance. These two interrelated factors are believed to be the primary cause of the reluctance of fish to enter the bypass and resulted in low guiding efficiencies."

D.4.1.3 Mayfield: Multidisciplinary

1. Zapel, E., T. Molls, S.V. Johnson, P.A. Nealson, and M.A. Timko. 2001. Evaluation of Juvenile Coho Salmon Behavior and Passage Through the Intake Louvers at Mayfield Dam in 2001 Using Acoustic Tags. Correlation of Acoustic Tag Tracking Data With Velocity Vector Field Generated With a 3-Dimensional Computational Fluid Dynamic (CFD) Numerical Computer Model. Velocity Field Verification With 3-Dimensional Point Velocities Measured in the Existing Intake With ADV Probe.

Organization: Tacoma Public Utilities, Light Division, Natural Resources Section
Project: Mayfield Dam
Type of Evaluation: Acoustic tag study and CFD analysis
Goals, Objectives, and Methods: The objective of the study was to asses the louver screen bypass biological efficiency and performance and correlate these results with the hydraulic characteristics of the intake system. The biological performance was evaluated by studying juvenile salmonid movement through the lover intake system with an acoustic tag study. The hydraulic conditions at the lover intake system were assessed with a computational fluid dynamic model.
Key Findings: Some areas within the intake exhibited poor biological performance. Many fish would approach the bypass entrance, and then reject it. Also, fish swam back and fourth through the louver vanes. The authors recommended making minor changes to the bypass entrance, such as paint or lighting, and then performing additional biological analysis on the modified bay to determine if these visual cues draw fish into the bypass system. The authors also recommend extending the CFD model domain and then modeling minor structural changes to the entrance slot and louver panels.

D.4.2 Cowlitz Falls Annotated Reference List

D.4.2.1 Cowlitz Falls: Engineering Design

1. ENSR. 2006. Post-Construction Hydraulic Verification of Cowlitz Falls Hydroelectric Project Prototype Fish Screen. Prepared for MWH and Tacoma Power. Final Report. 03830-014-1180. ENSR, Redmond, WA.

Organization: Tacoma Power
Project: Cowlitz Falls Dam
Type of Evaluation: Engineering design: prototype fish screen verification

Goals, Objectives, and Methods: The objective of the study was to confirm that the hydraulic performance of the Cowlitz prototype fish screen meets the design criteria specified in the design basis report. These criteria included a fish collection entrance velocity between 0.46 and 1.36 fps, a fish screen approach velocity component of less than 0.4 fps, a fish screen sweeping velocity component that is greater than the normal component, a fish screen transport velocity between 0.8 and 4.6 fps, a transport velocity gradient between 0 and 0.2 fps/ft, and a bypass flume entrance velocity of greater than 7 fps. To meet these hydraulic criteria the screen flow must be evenly balanced. In this study the screen approach velocities were balanced by measuring the flow at cross section of the screen transport channel located between screen panels and adjusting the backing bar porosity.

Key Findings: The verification field test data meet the hydraulic performance goals for the prototype system. The system has sufficient flow to attract fish to the system entrance and a smooth acceleration up the flume. In addition, the approach screen velocity component is small compared to the sweeping velocity component. Although all hydraulic criteria were satisfied and fish were observed entering the bypass flume, adults were observed turning around and swimming back toward the flume entrance after reaching the end of the flume. Biological testing is required to confirm the performance of the system.

2. MWH and ENSR. 2005. Prototype Fish Screen At Cowlitz Hydroelectric Project Design Basis Report.

Organization: Tacoma Power

Project: Cowlitz Falls Dam

Type of Evaluation: Engineering design: prototype fish screen design

Goals, Objectives, and Methods: The objective of the study was to design and install a prototype fish screen at the Cowlitz Falls Hydroelectric facility. The fish screen was to be installed in Spillway Bay 3 North to improve fish collection efficiencies from those with the existing fish passage facility. One dimensional spreadsheet calculations were used to calculate the hydraulic profile in the fish screen channel and develop the required screen geometry. A three dimensional computational fluid dynamics model (CFD) was then used to develop the head loss coefficient distribution that met the established performance criteria at the dominant turbine operating load.

Key Findings: Field data collected from the flow barrier baffle panel above the turbine intake trashracks to the fish transport flumes compared well with results from a CFD model of the spillway. The head loss coefficients determined form the CFD model were used to determine the appropriate backing plate porosity for each screen system. The CFD model could not account for all flow features that exist at the project site, hence field adjustment was required.

D.4.2.3 Cowlitz Falls: Physical Modeling

1. Hazara Northwest, Inc. and ENSR. 1993. Hydraulic Model Studies for Fish Collection Facilities. Bonneville Power Administration and Public Utility District No. 1 of Lewis County Cowlitz Falls Project. Final Report. ENSR, Redmond, WA.

Organization: Public Utility District No.1 of Lewis County

Project: Cowlitz Falls Dam

Type of Evaluation: Hydraulic model studies for fish collection

Goals, Objectives, and Methods: The objective of this study was to perform hydraulic physical models to support the design of fish passage facilities at Cowlitz Falls Dam. The fish passage facility design should provide an attraction flow system that uses the behavioral instincts of migrating fish and minimizes the effective flow withdrawal from the reservoir. In addition, the hydraulics at the fish passage facility should not detract from power generation.

Key Findings: The baseline hydraulic performance did not meet the fish passage design objectives, hence design development testing was conducted to determine the recommended modifications to the final design. These recommendations included:

1) Provide flow restriction baffles similar to those at Wells Dam.
2) Ports were included to provide a path for fish through the deflectors to reach the collection system without diving beneath the full draft of the structure.

3) A beam should be placed across the entrance to the embayment of spillway #4 during sluice gate operation.
4) The cofferdam and retaining wall elevations should be lowered.
5) The debris-passing flap gates located in the radial gates should be operated sparingly.
6) If flow fish the fish collection facility is to be returned to the forebay, it should be returned through an engineered outfall diffuser.

D.4.2.4 Cowlitz Falls: Multidisciplinary

1. Farley, J.M. , R.W. Perry, D.J. Shurleff, D.H. Feil, D.W. Rondorf, C.F. Morrill, and J.D. Serl. 2003. Migration Behavior of Juvenile Salmonids and Evaluation of a Modified Flume Entrance at Cowlitz Falls Dam, Washington, 2001. Prepared For Public Utility District No. 1. U.S. Geological Survey, Cook, Washington.

Organization: Public Utility District No.1 of Lewis County
Project: Cowlitz Falls Dam
Type of Evaluation: Biological analysis: migration behavior and fish flume entrance evaluation.
Goals, Objectives, and Methods: The objective of this study was to determine the downstream migration behavior of radio-tagged steelhead and cutthroat trout, determine if a modified flume entrance can increase juvenile salmon collection, and establish baseline information on the migration behavior of juvenile sea-run trout.
Key Findings: Travel times, migration rates, and residence times of radio tagged fish were dependent on flow characteristics and upstream travel behavior, as well as other factors. Migration rates were higher though free-flowing reaches, and lower through the reservoir. Overall, fish migrated quickly to the dam, but took longer periods of time to find a passage route through the dam. Fish made multiple trips upstream from the dam and milled in the baffle panel area. Most fish, when passing though the dam, chose the surface collection system. Decreasing the flow in combination with baffle changes increased the fish collection efficiency.

D.5 Miscellaneous/General Annotated Reference List

D.5.1 General: Engineering Design

3. ENSR and GEI Consultants. 2005. Surface Collector Concept Feasibility Study, Howard Hanson Dam, Green River. Submitted to Seattle District, U.S. Army Corps of Engineers. GEI Consultants, Inc., Lake Oswego, Oregon.

Organization: USACE Seattle District
Project: Howard Hanson Dam
Type of Evaluation: Concept feasibility study
Goals, Objectives, and Methods: The purpose of this document was to: 1) assess whether juvenile fish would more readily pass a surface-oriented passage route than through a proposed submerged screen and bypass route; and 2) identify the preferred surface collector alternative for possible incorporation into the final Howard Hanson Dam juvenile fish passage design for operation during pool elevations at or near Phases 1 and 2 full-pool levels. An extensive literature review was completed. After an initial study, six alternatives were selected for further development and rated on the basis of optimum hydraulic conditions for fish passage from the literature review, influence on existing design, costs, operations, and design uncertainty.
Key Findings: The literature review concluded that most fish approaching the submerged passage routes during the day delayed passing from the reservoir, at least until night. The review also affirmed that juvenile fish pass surface-oriented routes more readily than submerged entrances. The Hoisted, High-Velocity Weir with shaped transition upstream of the weir crest was recommended based on biological performance and other factors. A table with detailed ratings is presented. A surface bypass

discharge of 600 cfs was initially recommended, but was later revised to 300 cfs due to the cost of the large pumps that would have been required.

5. Johnson, G., A. Giorgi, C. Sweeney, M. Rashid, and J. Plump. 1999. High Flow Outfalls for Juvenile Fish Bypasses: Preliminary Guidelines and Plans for Research and Implementation- Final Report. BioAnalysts, Inc. ENSR, INCA.

Organization: USACE Portland District
Project: None
Type of Evaluation: Development of preliminary guidelines for high flow outfalls.
Goals, Objectives, and Methods: The objective of the study was to determine if modifications and/or additions to existing 1995 NMFS outfall criteria were warranted for high flow (>1,000 cfs) outfalls. If so, the further objective was to develop regionally supported, biologically based guidelines to locate and design high flow outfalls. The preliminary guidelines were developed through literature reviews of prototype biologic studies, physical hydraulic model studies, and calculations using data from prototype and physical model outfalls.
Key Findings: The biological and hydraulic differences between high flow outfalls (>1,000 cfs) and other outfalls (<1,000 cfs) were considered sufficient enough to warrant modification to 1995 NMFS criteria. The preliminary guidelines proposed in this report contain such changes. Additional laboratory and field research was considered necessary for two of the ten preliminary guidelines reported: receiving water characteristics (Guideline 2), and entry velocity (Guideline 8).

6. Northwest Fisheries Science Center. 2000. White Paper: Passage of Juvenile and Adult Salmonids Past Columbia and Snake River Dams.

Organization: National Ocean and Atmospheric Administration
Project: None
Type of Evaluation: Synthesis of scientific information on the passage of juvenile and adult salmonids.
Goals, Objectives, and Methods: The objective of this report was to synthesize the scientific information on the passage of juvenile and adult salmonids through the Federal Columbia Hydropower system.
Key Findings: Direct survival of yearling migrants is greater than or equal to the survival in the 1970's. Direct survival of Snake River subyearling fall Chinook is lower than for yearling migrants. The lowest subyearling survival occurs at low flows and high water temperatures. Direct juvenile migrant survival is highest through spillbays, with survival between 98 and 100%. Fish that pass through mechanical bypass screens often have increased levels of stress, descaling, and possibly delayed mortality. Typically, blood plasma levels rise dramatically during passage, but return to normal within several hours. There is great uncertainly about the indirect effects of hydropower system passage. Also, at this time the mechanisms of turbine mortality are poorly understood.
Several observations were also made about the adult fish passage system:

- Lamprey fish passage through the adult salmonid system is poor.
- Adult fallback at dams was as high as 15% and is an area of concern.
- Migration rates vary depending on factors such as species, year, season, and environmental concerns.
- It was difficult to compare passage at the various dams due to difference in sampling methods.

8. Pacific Northwest National Laboratory, BioAnalysts, ENSR, and Normandeau Associates. 2001. Design Guidelines for High Flow Smolt Bypass Outfalls: Field, Laboratory, and Modeling Studies. Final Report. Prepared for U.S. Army Corps of Engineers Portland District.

Organization: USACE Portland District
Project: Columbia River Dams
Type of Evaluation: Engineering design guidelines

Goals, Objectives, and Methods: The purpose of this study was to develop guidelines for design high flow fish passage outfalls. Three main research objectives were included in the guideline development and are as follows: (1) study the relationship between the direct fish injury/mortality rate in the out fall jet periphery and entry velocity, (2) establish the time history of exposure and turbulence associated with various entry velocities and flows, and (3) determine the relationship between an index of river bottom impact velocity and outfall discharge levels, plunge depth, and water depth. The field studies used to establish these relationships included releasing balloon-tagged juvenile salmonids at the Bonneville Second Powerhouse. Laboratory tests and model studies were also included in the analysis.
Key Findings: The recommended high flow outfall guidelines developed from this study were as follows:

- "Revise the entry velocity guideline (No. 8) to read: "Mean entry velocity for high flow outfalls can be up to 50 fps, and may be higher depending on site-specific conditions."
- Retain the preliminary bottom impact guideline (No. 2) until new information warrants a revision – "Receiving water characteristics, especially depth in combination with magnitude and trajectory of outfall discharge, are sufficient to prevent mechanical fish injury if they contact the bottom."
- Adopt the preliminary guidelines, with the caveat noted for Preliminary Guideline No. 2 (bottom impact) and the revision proposed for No. 8 (entry velocity)."

Some uncertainties still remain in the biology of high flow outfalls. The cross-sectional spatial distribution of smolts in a high flow outfall jet is still unknown. Also, the relationship between fish injury/mortality rate and equivalent bottom impact velocity is unclear.

16. Stone & Webster. 1995. Dewatering Functional Design Criteria. Surface Bypass and Collection System Dewatering System Field Investigation. Stone & Webster, Denver, Colorado.

Organization: USACE Walla Walla District
Project: Lower Granite, Little Goose, Lower Monumental, McNary, The Dalles, Rocky Reach, Wanapum
Type of Evaluation: Engineering concept design report
Goals, Objectives, and Methods: The purpose of this study were to: 1) perform full investigations of the Lower Snake and Columbia Rivers projects' existing juvenile fish facilities to determine baseline design, operational, and maintenance parameters; 2) identify dewatering systems that may apply to the surface bypass collections systems (SBCS); and 3) develop design criteria for dewatering system alternatives. The existing dewatering systems and fish collection and bypass facilities were evaluated based on inspections and interviews. A literature review of dewatering system research was completed and functional design criteria for dewatering systems was developed from which dewatering systems can be identified that would be applicable in the surface bypass and collection system.
Key Findings: Screening recommendations and criteria are presented for low and high velocity screening. Recommendations for screen type, materials, porosity control, sink control, cleaning, drafting mechanism, and dewatering facility configuration are presented. In addition, recommendations for each considered project are provided.

D.5.2 General: Biological Evaluation

5. Dauble, D.D., S.M. Anglea, and G.E. Johnson. 1999. Surface Flow Bypass Development in the Columbia and Snake Rivers and Implications to Lower Granite Dam. Final Report to U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington. Battelle.

Organization: U.S. Army Corps of Engineers, Walla Walla District
Projects: Bonneville 1, Bonneville 2, Ice Harbor, John Day, Lower Granite, Rocky Reach, The Dalles, Wanapum, and Wells dams
Type of Evaluation: Review and synthesis
Goals, Objectives, and Methods: The objective of this assessment is to summarize and evaluate development strategies and monitoring results for surface flow bypass systems in the Columbia and Snake Rivers. The study builds on previous reviews by Giorgi and Stevenson (1995), Johnson and Dauble (1995), and Johnson et al. (1997b). The authors emphasized concepts and results that apply to

further SFO development at Lower Granite Dam, particularly those data that may influence regional decision-making related to system improvements. While they recognized there are three main components to a SFO: forebay collection, conveyance, and outfall, their assessment focused mostly on the conditions, performances, and behaviors relative to forebay collection structures. The authors described SFO components, with emphasis on the forebay environment. Then they stated the basic premises for a successful SFO and provided a set of equations that can be used to quantify SFO performance.

Key Findings: The authors concluded the first three SFO premises (approach, discovery, and decision) were only generally supported by the data collected at Lower Granite Dam from 1996-1998. The most important breakdown in the SFO framework involved with forebay collection was lack of knowledge about smolt behavioral responses to specific hydraulic and environmental conditions. There are a competing myriad of environmental conditions present in the forebay environment. Each and/or all of several environmental stimuli operate over a range of measurement scales and influence whether a smolt decides to enter SBC. However, cause-and-effect analysis relative to SBC performance has focused almost entirely on local hydraulics. Other environmental variables, such as sound and light, should also be measured and factored into smolt behavioral response.

The authors noted use of SFO to pass juvenile fish has additional benefits that were not measured in the 1996-1998 SBC evaluations, including less stress, faster travel time, and lower dissolved gas concentrations. In particular, SFO complements spill as a smolt protection measure. For example, when SBC passage was combined with spill passage in 1998, spill efficiency and effectiveness almost doubled. The authors stated that surface bypass technology has considerable merit, particularly if development efforts support the natural tendencies or behaviors of smolts during downstream passage over dams. Site-specific features and a prototype structure will always be necessary in the development process.

10. Giorgi, A., G. Johnson, and M. Erho. 2000. Critical Assessment of Surface Flow Bypass Development in the Lower Columbia and Snake Rivers During 1995-1996M. Odeh. Advances in Fish Passage Technology. American Fisheries Society, Bethesda, Maryland. Pages 41-56.

Organization: U.S. Army Corps of Engineers, Portland and Walla Walla Districts

Projects: Bonneville 1, Bonneville 2, Ice Harbor, John Day, Lower Granite, Rocky Reach, The Dalles, Wanapum, and Wells dams

Type of Evaluation: General review and synthesis

Goals, Objectives, and Methods: The overall objective of this study was to critically assess surface flow bypass (SFB) development in the Columbia Basin, especially as it pertains to mainstem Columbia and Snake River dams operated by the Corps of Engineers. This paper was presented by A. Giorgi at the Bioengineering Symposium on Surface Flow Bypasses at the Annual Meeting of the American Fisheries Society, Monterey, CA 1997. The paper was based on the report by Johnson et al. (1997).

Key Findings: This paper describes five basic premises as a conceptual foundation for SFB development in the Columbia and Snake rivers: Bulk Flow; Preference; Zone of Separation; Opportunity for Discovery; and Entrance Conditions. Of the five premises, it is most important to have scientifically sound performance data to assess the opportunity for smolts to discover an SFB, and observations describing the entrance conditions, to evaluate various SFB prototypes and their operating conditions. SFB prototype strategies included: powerhouse channels; corner collectors; sluiceways with trashrack blockages; sluiceways with reconfigured entrances; unmodified sluiceways; and low and high volume surface spills. The authors stated that it was too early in the development process to draw conclusions about the efficacy of particular strategies. Overall, they concluded that SFBs offer improved smolt passage conditions at many large-scale hydroelectric dams, but thorough biological evaluation using a variety of research tools during SFB prototype development is essential.

11. Giorgi, A.E. and J.R. Stevenson. 1995. A Review of Biological Investigations Describing Smolt Passage Behavior at Portland District Corps of Engineer Projects: Implications to Surface Collection Systems. Draft. Don Chapman Consultants, Inc., Boise, Idaho.

Organization: U.S. Army Corps of Engineers, Portland District
Projects: Bonneville, John Day, and The Dalles dams
Type of Evaluation: Review and synthesis
Goals, Objectives, and Methods: This report surveyed existing biological investigations regarding smolt passage behavior as one of the initial steps in the Corps' new Surface Bypass Program. It focused on the relevance of the research findings to the design of SFOs.
Key Findings: This report provides a thorough summary of biological research as of 1994 relevant to SFO development at Portland District projects on the Columbia River. For Bonneville Dam, authors found that information was lacking to adjudge the preferred deployment position and design of a prototype SFO. For example, there were no data on the proportional split in passage between B1, spillway, and B2. Also, the available fish behavior information was deficient.
For John Day Dam, the authors noted the following major patterns: sockeye and Chinook salmon smolts were predominately oriented toward the Washington side of the river when the John Day River plume was evident and, as a consequence, were predisposed to pass in spill; steelhead and yearling Chinook passed the powerhouse and *deep* spill predominately during darkness; preliminary field tests indicated that *surface* spill can shift this to more balanced day-round passage, suggesting a method to reduce forebay residence times; although showing promise, surface spill was not adequately evaluated as a passage route; and, near field responses of smolts to changes or gradients in current velocity were not discernable in the available data.
For The Dalles Dam, the authors found that, based on the collective studies, 40-55% of the smolts pass via the sluiceway out of total project passage, when there is no spill, and a disproportionately large fraction of smolts pass via sluice discharge which is only about 2% of the total discharge for the dam. The authors suggested a general strategy for surface collection at TDA: provide surface spill and sluiceway discharge simultaneously 24 h/d and evaluate surface skim and vertical slot entrance configurations at each location.

16. Johnson, G.E., B.D. Ebberts, D.D. Dauble, A.E. Giorgi, P.G. Heisey, R.P. Mueller, and D.A. Neitzel. 2003. Effects of Jet Entry at High Flow Outfalls on Juvenile Pacific Salmon. *N. Amer. J. Fish. Manag.* 23.

Organization: U.S. Army Corps of Engineers, Portland District
Projects: All
Type of Evaluation: Field balloon tag and laboratory high velocity flume and physical scale model studies
Goals, Objectives, and Methods: The authors conducted field studies and laboratory experiments to determine the relationship between direct injury and mortality rates of juvenile salmon (*Oncorhyncus spp*.) and jet entry velocities characteristic of high flow (> 28.3 m3/s) outfalls at hydroelectric facilities. This research was motivated by the development of high flow surface flow outlet systems at USACE dams.
Key Findings: During field tests, the range of calculated mean entry velocities was 9.3-13.7 m/s for low (28.3 m3/s) and high (68.0-70.2 m3/s) outfall discharge rates and two receiving water elevations. Mortality and injury rates of balloon-tagged hatchery spring Chinook salmon juveniles in the field tests were less than 1%. At a high-velocity flume in a laboratory, small (87-100 mm fork length) and large (135-150 mm) hatchery fall Chinook salmon were exposed to velocities of 0.0-24.4 m/s in a fast-fish-to-slow-water scenario. Jet entry velocities up to 15.2 m/s provided benign passage conditions for the sizes and physiological states of juvenile salmonids tested under the particular environmental conditions present during this study. The authors concluded that direct injury and mortality results indicated that a jet entry velocity up to 15.2 m/s should safely pass juvenile salmon at high flow outfalls. It will be necessary, however, to conduct site-specific, post-construction verification studies of fish injury and mortality at new high flow outfalls.

17. Johnson, G.E. and D.D. Dauble. 2006. Surface Flow Outlets to Protect Juvenile Salmonids Passing Through Hydropower Dams. In Press: Reviews in Fisheries Science.

Organization: U.S. Department of Energy
Projects: All dams with surface flow outlets in the U.S., Canada, and northern Europe
Type of Evaluation: General review and synthesis
Goals, Objectives, and Methods: This paper synthesized available information to help guide future design considerations for successful SFOs. This review of available reports and publications covered 69 SFOs in Europe and North America.
Key Findings: The authors identified five main types of SFOs low-flow bypass/sluices, high-flow sluices, forebay collectors, powerhouse retrofits, and surface spills. Most low-flow bypass/sluices are sited in Europe and on the east coast of North America, where mean annual project discharge and hydropower production for the dams we reviewed were 95 m^3/s and 15 MW, respectively. The other four SFO types are found at dams on the west coast of North America with 2184 m^3/s mean annual discharge and 788 MW mean output. A conceptual framework based on fish behavior and hydraulics for different regions of a hydropower project was developed to evaluate SFO performance. For all SFO types, fish collection efficiency averaged 54%, with an average effectiveness ratio of 17:1 (fish to inflow). The authors concluded surface flow outlet technology can meet the goal of concurrent anadromous fish protection and hydropower generation.

D.5.3 General: Multidisciplinary

3. Johnson, G.E., A.E. Giorgi, and M.W. Erho. 1997. Critical Assessment of Surface Flow Bypass Development In The Lower Columbia and Snake Rivers. U. S. Army Corps of Engineers, Portland and Walla Walla District Offices.

Organization: U.S. Army Corps of Engineers, Portland and Walla Walla Districts
Projects: Bonneville 1, Bonneville 2, Ice Harbor, John Day, Lower Granite, Rocky Reach, The Dalles, Wanapum, and Wells dams
Type of Evaluation: General review and synthesis
Goals, Objectives, and Methods: This study provided USACE with a critical assessment of surface flow outlet development efforts to date (January 1997). The objectives were to: 1) describe basic premises of SFOs; 2) evaluate SFO development strategies relative to the premises; 3) describe research and evaluation efforts and lessons learned; 4) identify major information deficiencies and 5) critically assess the direction and plans for future SFO development at USACE dams. This report reviewed available publications and reports with emphasis on USACE dams.
Key Findings: The authors developed basic premises for SFO development within spatial zones in the forebay leading up to a SFO entrance. The premise topics were bulk flow, depth preference, zone of separation between turbine and SFO flow nets, opportunity for discovery, and entrance conditions. Biological performance data were assessed for various SFO strategies, including powerhouse channels, corner collectors, sluiceways with or without modifications, and surface spills. Examples of lessons learned are to understand fish approach paths and horizontal distribution before locating a SFO, integrate biological performance and hydraulic data whenever possible, and there are no “silver bullets.” The report noted four major information deficiencies: 1) environmental conditions smolts are sensing in the SFO intermediate and nearfields; 2) fine-scale smolt behavioral responses to environmental conditions; 3) integrated biological and physical data sets; 4) physical criteria for optimum entrance conditions that elicit the response of smolts moving into and using the SFO to pass the dam, i.e., the entrance conditions smolts prefer. The authors concluded that the Corps SFO Program was on a productive track. They offered the following recommendations:
- Annually revisit, clearly articulate, and widely communicate the goals of the SFB program for each District.
- Identify specifically what constitutes success in SFB development.
- Use the basic SFB premises as a foundation to develop and implement SFB strategies and design research and evaluation studies.
- For performance assessments, estimate SFO entrance efficiency, SFO efficiency relative to associated turbine units, and SFO efficiency relative to total project.

- •Study the effect of spill on SFB prototype performance.
- •Evaluate SFB performance under a range of river conditions if possible.
- •Have rigorous, statistically valid experimental designs.
- •Enhance presentation and facilitate interpretation of qualitative data by using three-dimensional visualization tools
- •Visualize flow fields in three-dimensions to show oblique components of the flow.
- •Continue refinement and development of pertinent SFB research tools.
- •Obtain useful information in the intermediate and near-field zones.
- •Build a research facility to investigate fish response to SFB entrance conditions.
- •Be cautious in applying SFO results at one dam to other dams.
- •Improve research and evaluation reporting times.
- •Schedule timely workshops to provide and share useful information soon after field work is completed while maintaining the quality and integrity of the data.
- •Improve coordination.

9. Sverdrup and ENSR. 1998. Lower Snake River Juvenile Salmon Feasibility Study, Lower Snake River, Surface Bypass and Collection System Combinations Design Report.

Organization: USACE Walla Walla District
Project: Lower Granite, Little Goose, Lower Monumental, Ice Harbor
Type of Evaluation: Engineering concept design report
Goals, Objectives, and Methods: The purpose of this report is to investigate, from an engineering perspective, each of the system combinations developed for review. The report includes discussions of alternatives for achieving these goals; engineering feasibility assessment of the chosen alternative; criteria and requirements concerning hydraulic, structural, mechanical, and electrical design; discussions of construction and operations and maintenance issues; and conceptual level cost estimates for engineering design, construction, and annual O&M. Four system combination alternatives were evaluated.
Key Findings: No particular system combination was recommended. A table of cost estimate summaries is presented in which engineering and design costs do not vary much across alternatives, but with significant annual O&M cost variations.

11. U.S. Corps of Engineers. 1995. Lower Snake and Columbia Rivers Surface Bypass and Collection Systems Prototype Development Program. U.S. Corps of Engineers, Walla Walla, Washington.

Organization: USACE Walla Walla and Portland Districts
Project: The Dalles Dam, Lower Granite Dam, Bonneville Dam, John Day Dam, Ice Harbor Dam
Type of Evaluation: Surface bypass and collection systems prototype development program document
Goals, Objectives, and Methods: The report describes the program for prototype development of surface bypass and collection systems on the lower Columbia and Snake Rivers. The purpose of the program was to develop and evaluate surface bypass and collection prototype concepts that will lead to permanent systems. The goal is to achieve or exceed the 80 percent fish passage efficiency (FPE) and 95 percent survival of fish passed. An adaptive management approach was adopted to allow flexibility to incorporate new information as data become available. The study steps prior to and during prototype development and construction are outlined and include investigating current and future methods of conducting biological related research and field testing, and developing accelerated but realistic schedules and costs.
Key Findings: None.

ENSR | AECOM

Appendix E

Review Comments

Comment Report: All Comments
Project: Surface Bypass Comprehensive Report
Review: 90%
Displaying 128 comments.

1890 ms to run this page

Id	Discipline	DocType	Spec	Sheet	Detail
1460968	General	Technical Report	n/a	n/a	n/a

(Document Reference: Abstract)

1st para. Capitalize "District" in "Walla Walla District"

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0 Evaluation **Concurred**
Revision made to text

Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07

Backcheck not conducted

Current Comment Status: **Comment Open**

Id	Discipline	DocType	Spec	Sheet	Detail
1460969	General	Technical Report	n/a	n/a	n/a

(Document Reference: Abstract)

3rd para. Capitalize "Rivers" in "Columbia and Snake Rivers".

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0 Evaluation **Non-concurred**
Style guides we have consulted indicate rivers should not be capitalized, where more than one river is described.

Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07

Backcheck not conducted

Current Comment Status: **Comment Open**

Id	Discipline	DocType	Spec	Sheet	Detail
1460970	General	Technical Report	n/a	n/a	n/a

(Document Reference: Table of Contents)

Update all page numbers in the TOC.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0 Evaluation **Concurred**
Revision made to document.

Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07

Backcheck not conducted

Current Comment Status: **Comment Open**

Id	Discipline	DocType	Spec	Sheet	Detail
1460980	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 1-1, 1st para. in Sect. 1.1)

Capitalize "River" in "Snake and Columbia River dams". Same comment in 2nd para., last sentence.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Non-concurred** Per response to 1460969 Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1460987	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 1-1, 1st para. in Sect. 1.1)

Suggest using "lower Snake" instead of "Lower Snake" (lower case "l") and dropping the "s" in "Rivers" in the phrase "...Snake and Columbia River hydroelectric projects...", unless the way it is currently written is how it actually is in the original document (the sentence is in quotes).

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1460992	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 1-3, Sect. 1.4)

A Chapter 5 is cited as containing the conclusions and recommendations, and there is such a chapter, but it's not listed in the Table of Contents.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** The Table of Contents will be updated. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1460995	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 2-2, Sect. 2.2)

D is defined as the vertical depth of flow in the equation for wave celerity. D is actually the Hydrualic Depth, which is the ratio of the water area to the top width, so it is only equal to the vertical depth of flow for rectangular channels. Suggest presenting a more accurate definition of D.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made in text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07

	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461068	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 2-3)

Be consistent in showing only English units or both English and SI units.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Only English Units will be used. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461078	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 2-3)

The flow ranges seem to be pretty precise for a general definition -- i.e. why not 1,400 - 11,000 cfs instead of 1,410 - 10,950 cfs?

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** The ranges were originally based on SI units in round numbers, but will be changed to round English units. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461085	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 2-3, 3rd bullet)

Capitalize "Rivers" in "Columbia and Snake Rivers".

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Non-concurred** Per response to 1460969 Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461089	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 3-16, 1st para.)

Figure 3-12 shows a profile view of the SBC, not a plan view as noted.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Text revised. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461098	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 3-20, Figure 3-14)

Suggest changing the "Future ASW" label to "Future RSW" if possible. Current thinking is that there will not be an ASW at Little Goose.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461113	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 3-20, 1st para. in Sect. 3.3.3)

Last sentence. The LoMo RSW design is done; installation has started. Suggest saying the "installation process" or the "implementation process" is ongoing rather than the design process.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461118	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 3-20, 2nd para. in Sect. 3.3.3)

2nd to last sentence about low risk of cavitation is redundant. The previous sentence already stated that based on model study results the preferred RSW design had reduced cavitation potential.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461119	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 3-20, 2nd para. in Sect. 3.3.3)

Last sentence. Should note where the centerline velocity will be in the 6.2 - 7.4 fps range with reference to the crest. Is this at the crest? At the entrance (pier noses)? Does the range cover the whole distance from the entrance to the crest? Based on the magnitude of the numbers, it seems likely the noted velocity range is only near the entrance; velocity near the crest is likely somewhat higher.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Revision made per Lynn Reese 1482254 Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461120	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 3-20, 2nd para. in Sect. 3.3.3)

Should note what capture velocity is assumed (7 fps? 8 fps?) for the noted velocity gradient range.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Revision made per Lynn Reese 1482254. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461131	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 3-21, 1st para.)

Suggest modifying the sentence that says, "Bay 8 can be operated...favorable tailrace conditions; therefore, Bay 8 was selected ..." This makes it sound like the training spill issue was the only reason why Bay 8 was selected, or at least the primary reason. The bay selection was based on multiple reasons, as described earlier in the paragraph. Suggest ending the sentence at the semicolon and starting a new sentence to say something like "For these reasons, Bay 8 was selected...".

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Revision made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461134	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 3-22, 3rd para.)

Add a "the" between "approach" and "project" -- "...in an area where fish approach the project..."

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Revision made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461136	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 3-23, 3rd bullet)

Capitalize "Harbor" in "Ice Harbor"

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Revision made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461143	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 3-24, last para.)

The second sentence indicates that Figure 3-19 shows the nappe intersecting the the ogee above the tailwater elevation, but Figure 3-19 does not show the nappe at all.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Text has been revised to clarify the figure reference. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461149	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 4-2, 1st line)

Delete "at" in "...both have powerhouses at located in channels..."

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Revision made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461155	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 4-2, last para.)

Replace the dash after "The RSWs" with a comma. As written, it indicates that the B2 Corner Collector, the New Wanapum SFO and The Dalles sluice are RSWs.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Revision made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461158	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 4-4, 1st para. in Sect. 4.2.2)

Capitalize "Rivers" in "Columbia and Snake Rivers".

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Non-concurred** Per response to 1460969 Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461181	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 4-12, Table 4-6)

Suggest using symbols or colors that show better distinction when printed in B&W if this document will be distributed electronically for people to print themselves. The yellow circle for 3 doesn't show up at all, and the shading for the green and red are too close to tell any difference when printed in B&W. If only color hard copies will be distributed, this is not an issue.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Table has been eliminated in response to other comments. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461183	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 5-3, 1st para. under "Outfall")

Capitalize the "River" in "Snake and Columbia River SFOs".

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Non-concurred**

	Per response to 1460969 Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461188	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 5-3, 1st para. under "Outfall")

Revise the 3rd sentence that starts, "Although special operations...". As written, this is not a complete sentence.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** This entire section has been re-written in response to other comments. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461193	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 5-3, 2nd para. under "Outfall")

The lead-in sentence for the bullet group is confusing. Is the "SFO Design Guidelines" supposed to be an underlined heading, following by the lead-in sentence, that was apparently truncated on the front end?

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** The entire section has been re-written in response to other comments. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461199	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 5-5, 3rd para. in Sect. 5.3)

Add "ed" to the end of "designed" in the sentence "...with specially designed entrance shaping...".

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461206	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. 4-15, Figure 4-1)

The drawing for Little Goose can be updated to show the SFO located at Bay 1 (south end of the spillway just before the powerhouse). The RSW location has been determined to be in Bay 1.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made to drawing. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461215	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. A-2, last para.)

Add "and" in "We must consider and understand the factors...". Add "the" in "...possibly temperature gradient in the river basin.".

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Changes made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461222	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. A-3)

Suggest using the word "discharge" instead of "Q" in Doug Cramer's comment, unless the symbol is defined.

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made to text Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461225	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. C-54)

1st bullet in A) 2). Add an "s" to the end of "projects". Spell out Lower Monumental rather than using LO-MO. 2nd bullet in A) 2). Replace "when" with "with" in "...to the powerhouse with high powerhouse flow." Or add to the end of the sentence to say "...to the powerhouse when high powerhouse flow occurs."

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07

	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461228	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. C-55)

Last dash under "Surface Bypass bay selection" bullet: Replace "bay" with "may".

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1461230	General	Technical Report	n/a	n/a	n/a

(Document Reference: p. C-57)

Show units (feet) for the forebay elevation range shown under "General Stats".

Submitted By: Sean Milligan ((509) 527-7535). Submitted On: 13-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466870	Design Team Leader	Technical Report	n/a	n/a	n/a

Table of contents needs to have Section 5

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Table of Contents updated. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466872	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: 1-1 2nd sent.)

Recommend replacing "instigated" with "initiated".

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466874	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: Section 1.4 last sentence)

Consider revising to "A list of acronyms and terns is provided on a foldout at the end of the report."

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466877	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: Aerial Photos)

Some photos are difficult to read because fo the small size. Consider putting in larger size photos, say maybe the size of Fig. 3-4 for example.

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Photos re-sized to Figure 3-4 example. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466879	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: 3.2.4 second sent.)

Replace 118,304 cfs with 118,300 cfs.

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466897	Design Team	Technical Report	n/a	n/a	n/a

	Leader				

(Document Reference: 3.4.2, 2nd sent.)

remove "the Portland Distirct's" from that sentence.

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466900	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: p 3-27 2nd para. 1st sent.)

Remove all caps from THE DALLES

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466908	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: Para. 3.4.5)

General - references to B2 "surface sluice chute" should be changed to "ice and trash chute". The "ice and trash chute" is what the structure is known by.

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Searched document for "surface sluice chute" and replaced with "ice and trash chute" Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466917	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: pge 3-33, 2nd para. 2nd sent.)

Change, "The old sluice..." to "The existing ice and trash...".

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466923	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: page 3-33, 2nd para., 2nd sent.)

sp. "just"

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Change made to text. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466928	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: page 3-37, last para. last sent.)

Clarify "rid-lid"

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Text changed to read "rigid lid." Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1466932	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: page 3-41, last para. last sent)

Revise to "3000" cfs.

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 19-Apr-07

1-0	Evaluation **Concurred** Text change made. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1469395	Natural Resources	Technical Report	n/a	n/a	n/a

General: Substantial progress has been made in providing details. This product is much more comprehensive that the

60% draft. The authors did a commendable job responding to and incorporating additional material in response to review comments.

Submitted By: Dennis Dauble (509-376-3631). Submitted On: 23-Apr-07

1-0	Evaluation **Concurred** Thank you! Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1469402	Natural Resources	Technical Report	n/a	n/a	n/a

Chapter 3: • Any estimate of loss of power production for operation of the Wells SFO? (p. 3-4). • Missing the spillway in Figure 3-3 and appendix version of the same. • I found the summary of Wanapum Dam (3.2.4) to be somewhat confusing. What about the FUFB will make it better than the SAC? (and, what is the future of the future unit bays?) • For the lower Snake River projects, terms like "biological test" need definition (i.e., what types of tests constitute biological?). How the biological performance indices were "averaged" for LGR is not clear. Several paragraphs allude to extensive biological investigations. Please give examples of what they were. • Please provide more detail to the legend of Table 3-7. It is not intuitive what dates are used for the various metrics. I believe that the Y. Chinook, Steelhead (wild), and Steelhead (hatchery) numbers are spring. However, these FCF numbers (7.7, 8.3, 8.5) do not average to 10.0 (Run-at-Large Spring). Same is true for FCE. Thus, I was left wondering how the numbers were built. • 3 SFO design alternatives were identified for B1 (page 3-30). Was only one tested? (tie off the thought). • Each project description would benefit from identifying the species of interest and information or a graphic on composition/timing. • Of the Other PNW projects (3.5), Cowlitz Falls and PGE Round Butte appear to be the most challenging to assess performance. Cowlitz Falls because of the odd "transport velocity." Round Butte (3.5.4) because of what I believe is a mixed objective approach (i.e., is the primary goal water quality or fish passage?). Can you address the challenge of mixed objectives? Cowlitz (3.5.2) has statements like "should provide adequate fish passage." (p 3-37) and "was determined to have sufficient flow to attract fish to the system entrance....". What info are these statements based on? Add measurement scale to Fig 3-34. Is there any information on studies from North Fork (3.5.6)? i.e., FCE, the median reservoir residence time, and fish passage related to flow?

Submitted By: Dennis Dauble (509-376-3631). Submitted On: 23-Apr-07

1-0	Evaluation **Concurred** An estimate of power production loss will be difficult as it will vary with the annual river run-off hydrograph, etc. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 26-Jun-07
1-1	Backcheck Recommendation **Close Comment** Chapter 3 - An estimate of power production loss will be difficult as it will vary with the annual river run-off hydrograph, etc. Figure 3-3 - Accepted. Text and arrow added to photos. FUFB - Accepted. Explanatory text added. Biological tests - Accepted. Explanatory text has been added where appropriate. 3 SFO design alaternatives - Accepted. Confusing text has been removed. Species of interest - Accepted. A general description of species of interest has been added at the beginning of Chapter 3. Round Butte (3.5.4) - Accepted. A statement clarifying the interrelated goals of water quality improvement and fish passage has been added to the text. Cowlitz (3.5.2) - Accepted. The statements about the Cowlitz design and performance objectives have been clarified. Measurement scale to Figure 3-34 - Disagree. Figure 3-34 is a rendition and addition of a scale is not appropriate. Scale drawings are provided in Appendix C. North Fork - Accepted. A reference has been added to the text directing the reader to Appendix C. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
1-2	Backcheck Recommendation **Close Comment** Closed without comment. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Current Comment Status: **Comment Closed**

1469409	Natural Resources	Technical Report	n/a	n/a	n/a

Chapter 4 • Project Layouts (4.1.1) and supporting graphics was helpful although not sure why Figure 4.1 was at the end of the chapter. I like the binning of linear versus split versus "Z" projects. • I found some definitions lacking in Hydraulic Profiles (4.1.2) such as "critical entrance flow regime", "central bio-index". As for Figure 4.1, why were Figures 4.2 and 4.3 at the end of the Chapter? This is inconsistent with the style of the rest of the document. • top of page 4-3: where is the 3 fps velocity relative to 13 fps (distance)? • p 4-4, identify spring-migrating yearling migrants (i.e., steelhead, Chinook, sockeye?) • Please explain the correlation analysis in Figure 4.3. It seems that many of the low "correlation" variables are based on non-scaled measures of the SFOs. Shouldn't proportion be considered (see below comment on spatial extent). Overall, I don't think these figures are of much value. • The relationship between the data in Table 4-1 and 4-2 (and 4-5/4-6) was not self-evident. Perhaps more detail could be provided in the Table legends. •Would a statistician agree with the use of the term "correlation analysis?" (as used in section 4.3) • The meta-analysis (Section 4.4) is a good start on sorting out the "big-picture" perspective. • It was challenging to go see the connections among Table 4-3, Figure 4-4, 4-5, and 4-6. For example in Table 4.3 could be linked to Table 4 by using V, H, E to show alignment to headers of vertical (V), horizontal (H) and Entrance (E) features in Table 4.4. The text needs additional narrative of the metrics used across the top of the table under Discovery and Decision Zone (Table 4-3). Also elaborate on the concepts of encounter probability and capture probability. • It was not clear that the spatial extent of SFOs entrance is addressed. (e.g., strain field in 4.4.2). There are values such as 7 fps used as trapping velocity. If I do the math right, this equates to the burst speed of a 22 cm smolt (10 BL/sec). What is the 5 ft minimum distance for avoidance behavior based on? Vision? Sound? These facts feed the rating score for Table 4-4 and performance for all the SFOs! • The horizontal/vertical distribution of smolts as described in the rating criteria (Table 4-4) is related to the proportion available to the SFO; also in Table 4-3 "Fish known to congregate." However, lacking is analysis of entrance size (volume/area) relative to the forebay cross/section relative to where high densities of smolts are available because that's where they migrate or that's where they congregate. The shallow vs deep part of vertical distribution ratings are also in question unless the depth values selected are justified or normalized.

Submitted By: Dennis Dauble (509-376-3631). Submitted On: 23-Apr-07

1-0	Evaluation **Concurred** Figure 4.1 - The oversize foldout figures are located at the end of the chapter for the reader's convenience in reading the text and referring to the figures. I found some definitions lacking - The definitions used throughout Chapter 3 are described in Section 3.1, which introduces this material. Where is the 3 fps velocity relative to 13 fps - Accepted. Explanatory text describing the velocity locations has been added. Low correlation - Accepted. The correlation analyses figures have been moved to Appendix B and the reference in the text revised. The meta –analysis - Accepted. This chapter has been extensively re-written to address the remainder of this comment, as well as those by other reviewers. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1469410	Natural Resources	Technical Report	n/a	n/a	n/a

Chapter 5 • The argument for removing the Discovery premise is satisfactory, but I am left with wondering what the vertical distribution premise is. That is, where are we with the overall concept? • Re-casting the Decision Premise based on the SVPH was not well developed. Trapping velocity appears to be the key point. • Suggest a clean break (subheading?) after the Outfall paragraph to get to the SFO Design Guidelines (that first sentence has bonus words). Additional detail of the design guidelines with respect to distance and forebay bathymetry would be helpful. The concept of competing flows was confusing. • Missing in the Development Process Model (5.2) was migrating timing. • Estimates of discovery and entrance efficiencies (Information Deficiencies, 5.3) could include better definitions of how to measure, consistency guidelines, and how to deal with scaling.

Submitted By: Dennis Dauble (509-376-3631). Submitted On: 23-Apr-07

1-0	Evaluation **Concurred** Chapter 5 has been extensively re-written to move the premises update to Chapter 2 and to address the remainder of this comment, plus those by other reviewers. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted

	Current Comment Status: **Comment Open**

1482241	Hydraulics	Other	n/a	n/a	n/a

(Page 2-3, paragraph 2.4 (Conceptual Framework) and Table 2-2 on page 2-5). I would suggest noting this version of Premises as original (even with the original date?) which will help differentiate it from the new one in Section 5 which is based on considerably more data.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The revision of the conceptual framework has now been combined with the base description in Chapter 2. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482242	Hydraulics	Other	n/a	n/a	n/a

(Page 3-5, 5th bullet) This sentence is taken from another source so you may not want to consider changing it anyway, but it states that the entrance efficiency for Wells (along with the discovery efficiency) must be at least 89% on average since the FCE was 89%. It seems for the entrance efficiency term the way I believe we define it (at least as it relates to hydroacoustics), the same fish might go past an entrance several times before finally deciding to go in. If this happened at Wells (which we probably don't know), the entrance efficiency might have been lower / would correlate better with what has been observed at other low velocity entrance projects.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

Revised 04-May-07.

1-0	Evaluation **Non-concurred** The text as written is an accurate reporting of the analysis performed and reported by others Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482243	Hydraulics	Other	n/a	n/a	n/a

(Page 3-16, second sentence) The SBC view shown on Figure 3-12 is a profile view, not a plan view as listed. However, adding a plan view picture (even though one is already shown in Appendix C) might be helpful since there is quite a bit of discussion about entrances and the BGS.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The text has been revised to fit the figure. The plan view has not been added in order to be consistent with the other project synopses. More detailed drawings, plan and profile, are provided in Appendix C. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482245	Hydraulics	Other	n/a	n/a	n/a

(Page 3-16, last paragraph) Regarding one of the comments made by Blaine Ebberts during the 60% review (#1435177 – "either it worked or it didn't"), a big reason why the SBC concept may have merit in the future is from the perspective

of an SBC working in combination with the intake screen system (i.e. "a hybrid"). A hybrid system based on the data collected might be used to pass more fish safely and more economically past the project (via in-river and / or transport routes) relative to what surface spill or turbine intake screens can do alone. I think it would be helpful to add this thought at this location or in the last paragraph under the Lower Granite section (pg. 3-19) where this idea is already mentioned. Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07					
1-0	Evaluation **Concurred** The comment was added. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1482246	Hydraulics	Other	n/a	n/a	n/a
(Page 3-16, last sentence and page 3-17, first sentence) Thinking about another one of Blaine's comments made during the 60% review (#1435178 – "explain rationale for moving from the SBC (powerhouse retrofit) concept to the RSW (surface spill) concept"), the RSW concept was identified initially for Ice Harbor (bypass only) in the Corps' Lower Snake River Feasibility Study. The early plan was to test this concept at Ice Harbor, but because of all of the research / learning that had taken place at Lower Granite with the SBC (plus there was other structures that could be tested in combination with the RSW - the partial powerhouse SBC / SWI occlusion and the BGS), it was decided to do the concept development test testing at Lower Granite instead. (This thought connects to my 60% review comment [#1422223]. It might be better to insert these thoughts / language in place of the two sentences referenced from Sverdrup and ENSR. Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07					
1-0	Evaluation **Concurred** The additional explanation has been included. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1482247	Hydraulics	Other	n/a	n/a	n/a
(Page 3-16, second paragraph, second sentence) I would suggest modifying the SWI description in order to provide a better picture / contrast relative to other efforts in the region to improve fish passage performance by blocking trashracks. I would suggest changing, - "The SWI was retrofitted to the bottom of the SBC in 1998 to block the upper 17% of the intakes at Turbine Units 4-6 to create a deep draw for turbine flows, like that at Wells Dam, with the intent of decreasing entrainment of juvenile salmon downward to the turbines and increasing their availability to the SBC." To something like: - "The SWI was retrofitted to the bottom of the SBC in 1998, effectively changing the roofs of the intakes at Turbine Units 4-6 from 50-feet deep (with gradual roof slopes) to 70-feet deep (with abrupt horizontal roofs that extended through the trash racks into the intake itself). See the SBC profile in Figure 3-12. This was done to try to decrease the entrainment of juvenile salmon downward to the turbines and to increase their availability to the SBC. The SWI was designed to match (as close as possible) the Wells Dam flow line approach and intake roof shape / depth." Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07					
1-0	Evaluation **Concurred** The suggested text revision was made. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1482248	Hydraulics	Other	n/a	n/a	n/a

(Page 3-17, paragraph between Figure 3-12 and Table 3-6) Nothing is mentioned about any effects (potential / good / bad) regarding the influence of the SWI. Is there any inferences or judgments we can make about the SWI in this document? It seems like there were observations made in 1998 (first year of the SWI) that fish were higher in the water column / moving upward relative to 1996 and 1997 tests. It can not be said that the SWI alone improved SBC performance (because other changes like the BGS and different entrance operations were occurring at the same time), but can we say that we believe it was a positive factor in helping to improve SBC performance?

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** We will make a statement relative to effects of SWI influence if any are apparent in the data. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482249	Hydraulics	Other	n/a	n/a	n/a

(Page 3-17, Table 3-6, * footnote) The estimated value should be "0.62", not "0.062".

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The estimated value will be verified and corrected if warranted. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482250	Hydraulics	Other	n/a	n/a	n/a

(Page 3-18, 1st paragraph, last sentence). Insert the word "the" before "entire spillway ....."

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The text was revised. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482251	Hydraulics	Other	n/a	n/a	n/a

(Page 3-18, Table 3-7 and page 4-4, Table 4-1) Summer RSW information should be available for all of 2005 and 2006. (Check with Tim Wik).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The information will be included if readily available from Tim. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482252	Hydraulics	Other	n/a	n/a	n/a

(Page 3-19, 3-20, 3-24, first paragraphs of general descriptions for Little Goose, Lower Monumental, and McNary) Suggest making project descriptions follow the same format / level of detail that is used for Lower Granite and Ice Harbor. Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07					
1-0	Evaluation **Concurred** The suggested additions will be made. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1482253	Hydraulics	Other	n/a	n/a	n/a
(Page 3-20, Figure 3-14) Picture contains the term "ASW". Since I don't believe this term is used anywhere prior to here, it would be best to either change it to "RSW" or to have some discussion in the text about ASW. Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07					
1-0	Evaluation **Concurred** Text box on photo has been changed. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1482254	Hydraulics	Other	n/a	n/a	n/a
(Page 3-20, last sentence) The hydraulic description for the Lower Monumental RSW doesn't fully match what is presented in Fig. 4-2 in Section 4 (plus it lists centerline velocity data, etc. that without more detail makes it a little difficult to fully understand all of its significance). It might be best to just reference the discharge and to refer the reader to Fig. 4-2 for additional data. (This comment might apply to all the projects where hydraulic information is presented in Fig. 4-2). Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07 Revised 04-May-07.					
1-0	Evaluation **Concurred** The suggested change has been made to all applicable project synopses. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1482255	Hydraulics	Other	n/a	n/a	n/a
(Page 3-22, next to last sentence in first full paragraph and Appendix C, page C-65, bullet under C)3)). The wording implies that track racks were blocked during testing. The gate slot structure was actually above the intake roof / above the track racks. (Modify the wording accordingly). Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07					
1-0	Evaluation **Concurred** The text revisions were made.				

	Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482256	Hydraulics	Other	n/a	n/a	n/a

(Page 3-22, next to last sentence) Discovery and entrance efficiency data were not reported, but I believe verbal communications with researchers (hydroacoustics and radio tracking) would state that there was no indication of fish passing "anywhere close" to the RSW (whatever that might mean) showing delay in passing over the RSW once they sensed the flow field. (Tim Wik is checking with researchers to get there thoughts / need to follow-up with Tim).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

Revised 04-May-07.

1-0	Evaluation **Concurred** A personal communication with Tim Wik will be added if available or no change will be made. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482257	Hydraulics	Other	n/a	n/a	n/a

(Page 3-22, last sentence and possible new bullet on page 3-17) Add in this sentence (or add a new one?) that "It was observed that the amount of spill occurring in association with RSW operations significantly impacted FCE values. (See the bullet list on the next page for additional information)". A new bullet to consider adding to page 3-17 on the above topic might look like: . "The amount of spill in association with RSW operations will significantly impact RSW performance. For example, for the two 2006 test treatments for yearling chinook, FCE was 51.3% and 33.1% when overall average spill was 33% and 58%, respectively").

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

Revised 04-May-07.

1-0	Evaluation **Concurred** The text additions will be considered. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482258	Hydraulics	Other	n/a	n/a	n/a

(Table 3-9, page 3-23). Add summer results from 2005 and 2006. (Check with Tim Wik). These values would also reflect in Table 4-1 on page 4-4.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The information will be included if readily available from Tim. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482259	Hydraulics	Other	n/a	n/a	n/a

(Page 3-23, first bullet) Suggest inserting the wording in parenthesis to the following sentence: . On average, the sluiceway (with no voluntary spill occurring) passed 32% of .....1986).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

Revised 04-May-07.

1-0	Evaluation **Concurred** Text change made. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482260	Hydraulics	Other	n/a	n/a	n/a

(Page 3-23, third bullet) I would suggest eliminating this bullet. Getting 40 to 42% FCE during the spring (and greater than 60% FCE during the summer) even when the percent spill is high would indicate the word "potential" may not be the best term to use. We can say that we are still trying to figure out how best to operate RSW's given project / system goals plus we are looking at ways to make them better [i.e. different project operations, potential BGS's, etc.]).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The text will be modified as appropriate. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482261	Hydraulics	Other	n/a	n/a	n/a

(Page 3-23, possible new bullet) Can we say (based on the 2005 hydroacoustic data) that it appears FGE was increased during RSW operations versus no RSW? (Need to check with Tim Wik / researchers).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The statement will be added if Tim Wik and data concur. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482262	Hydraulics	Other	n/a	n/a	n/a

(Page 3-24, third sentence after Fig. 3-18) Suggest eliminating this sentence ("The model results showed that the approach velocity field on the centerline of the TSWs was similar to previously tested RSW [ENSR 2006]" Figure 4-2 and other related information does not support this.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The statement has been removed. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted

	Current Comment Status: **Comment Open**

1482263	Hydraulics	Other	n/a	n/a	n/a

(Page 3-29, 4th bullet) Would suggest inserting additional wording (CAP words in next sentence) since turbine intake occlusion (given possible refinements in design, etc.) may still have some merit in the future. "Turbine intake occlusion using the J-BLOCK DESIGN did not appear to substantively enhance sluiceway passage (Johnson et al. 2007)."

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

Revised 04-May-07.

1-0	Evaluation **Concurred** Text change made. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482264	Hydraulics	Other	n/a	n/a	n/a

(Page 3-12, Fig. 3-12 and Fig. 4-2 in Section 4) The entrance velocity shown in Fig. 3-12 (for B1 PSC) does not correspond to that shown in Fig. 4-2. (Double-check number).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** I think you mean Page 3-30, Table 3-12 and Figure 4-2. The numbers will be reconciled. It appears the value in Figure 4-2 corresponds to the 3.8 fps entry in Table 3-12. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482265	Hydraulics	Other	n/a	n/a	n/a

(Page 3-32, 2nd bullet) The statement is made that trash rack occlusion as a means to increase sluiceway passage was not promising. This would be true based on the tests that were completed, but it seems that the PSC might have demonstrated (or at least the door might still be open) that a surface passage device extending down in front of the intake (a flat floor on the bottom of the PSC extending down in front of the intakes versus purely blocked trash racks with abrupt contraction / expansion flow lines) in combination with an attractive higher flow surface passage route may still have merit. I'm not sure how best to word this (or if it needs to changed), but this might be an important thought in the future to keep in mind.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The text has been revised to acknowledge the result only for the actual test configuration. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482267	Hydraulics	Other	n/a	n/a	n/a

(Page 3-37, 2nd paragraph, 4th sentence) My limited understanding of the turbulence test at Cowlitz Falls is that fish were influenced / guided by the induced turbulence, but the fact that there was no noticeable improvement in FCE may be more attributed to poor entrance conditions at the SFO. It might be that no more can be said, but it may be worth one more check with Tim Wik (and others?) regarding the effectiveness of the turbulent flow devices independent of the

FCE results.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The statement has been modified to reflect other possible causes of the FCE results. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482268	Hydraulics	Other	n/a	n/a	n/a

(Page 4-2, last paragraph, 2nd sentence) I believe the statement; "All but The Dalles have similar velocity, acceleration, and gradient profiles." is incorrect. Based on Fig. 4-2 (and doing some additional analysis on the side using Fig. 4-2 as the foundation), it appears there are noteworthy differences between projects. For example, the acceleration difference between the B2 corner collector and the Ice Harbor RSW [upstream of a capture velocity] is significant. I would suggest checking this section and rewriting segments to better reflect the differences.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** Figure 4-2 is being revised in light of new data provided since the 90 % draft was written and the descriptions in Section 4.1.2 will be revised accordingly. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482269	Hydraulics	Other	n/a	n/a	n/a

(General Comment, pages 4-3 ... 4-13, Sections 4.2, 4.3, and 4.4) I have concern regarding how the bio-index / meta-analysis is being used to help develop correlations. (Also see Comment 1482277 for additional related thoughts and suggestions). The bio-index as discussed in these sections can be used to safely characterize SFO performance in a general way (Section 4.2), but it seems it would be misleading if it is used much beyond this (Sections 4.3 and 4.4) where (for example) there are significantly different levels of spill for different projects or if test results were averaged over several different treatments / years where "top-performers" in select year results might in actuality be best used for comparison purposes. Rather than do an overall comprehensive comparison rating / summarization between projects using "generic" type data (i.e. the meta-analysis), it might be better to incorporate key foundational thoughts and points that can be gleamed from this effort into a discussion (say in Section 5) where this information can be used as part of the overall effort to collectively summarize (in a more simplistic manner) key observations and lessons learned. An example of what is being suggested above might be to compare (using Figure 4-2) near field hydraulic and fish performance differences between lower velocity entrances (e.g. Wells Dam, Rocky Reach, Lower Granite SBC "early years") versus "fish efficient" transition entrances (e.g. RSW's) versus higher flow / "non-efficient" entrances (e.g. Lower Granite SBC "later years", B2 Corner Collector) versus higher flow / "flow efficient" entrances (e.g. new Wanapum, McNary TSW). Out of this discussion, you might be able to come up with a collective set of observations and key points (some of which may be saying we will be getting additional data in the future that will add additional insights).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

Revised 04-May-07.

1-0	Evaluation **Concurred** This section has been revised considerably based on these comments and those of other reviewers. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted

	Current Comment Status: **Comment Open**

1482270	Hydraulics	Other	n/a	n/a	n/a

(Page, 4-4, Table 4-1) Insert summer data for Ice Harbor and Lower Granite RSW's. (Contact Tim Wik for data).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The information will be included if readily available from Tim. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482271	Hydraulics	Other	n/a	n/a	n/a

(Page 4-7, Table 4-3, and page 4-9, Table 4-4) The performance characterization for features and the rating criteria shown in these tables (particularly vertical distribution and entrance conditions) is very subjective. I believe some of these thoughts / observations can be safely carried into the discussions in paragraph 4.5 (key observations) and / or Section 5 (Discussion and Recommendations), but there needs to be considerably more discussion before this information can be used as "criteria" if we are going to try to use this information for ranking / correlations purposes.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** This section has been revised considerably in light of this and other reviewers comments. The analysis now uses more explicit criteria and less subjective levels. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482273	Hydraulics	Other	n/a	n/a	n/a

(Page 4-8, 3rd and 4th paragraphs, and page 5-2, Section 5.1.3, Decision) Suggest the NFS / SVP discussions be reviewed by Andy Goodwin to make sure what is being said is consistent with his understanding of SVP / fish behavior and hydraulic correlations.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** Andy Goodwin provided review of the report in subsequent comments. We have eliminated our use of the SVP hypothesis to support our evaluation of SFOs, but suggest instead that this hypothesis be considered in future work in cooperation with Andy. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482274	Hydraulics	Other	n/a	n/a	n/a

(Page 4-13, first bullet) It's mentioned that the SFO type is not a primary factor affecting forebay collection efficiency, but it seems there may be characteristics within different SFO types that would be important to highlight / could suggest different SFO types might in fact be more effective if we had a better understanding of fish behavior and hydraulics. More discussion on this key observation would make it more meaningful.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The statement has been revised to point to the other overriding factors contained further on in the same discussion. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482275	Hydraulics	Other	n/a	n/a	n/a

(Page 4-13, 3rd bullet) The statement "A hydrocombine structure does not guarantee success" is a true statement. However, it would be helpful / more meaningful if you expanded the discussion (possibly saying more in the last sentence regarding the significant size and flow differences between Wells and Cowlitz).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** The discussion has been expanded to address the effect of scale and size of facility. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482276	Hydraulics	Other	n/a	n/a	n/a

(Page 4-13, 4th bullet, last sentence) I'm not sure I agree (if I understand it correctly) with the thought communicated in the last sentence. ("However, these competing flows do not appear to be problematic [Table 4-3]]"). It seems like the details of the approach hydraulics / water depths as well as the competing flow volumes themselves are a critical part of the near field equation in terms of having success. (For example, what performance insights can we gain by comparing Wells Dam and the Lower Granite SBC ["early years" and "later years"] data)?

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** This bullet has been revised in consideration of this and other reviewers' comments. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482277	Hydraulics	Other	n/a	n/a	n/a

(General Comment related to page 4-13, Section 4.5 [Key Observations] and pages 5-2 / 5/3, Section 5.1.3 [SFO Zones / Guidelines]) It might be better (from an organizational and understandability perspective) to combine key observations, lessons learned, guidelines etc. from the different paragraphs / sections into one common section. One possible way to structure this information (and then to summarize into a table) might be as follows: - Have 5 major zone regions (Approach, Discovery, Decision, Conveyance, Outfall) - Within each zone, have three categories for key discussion points: . Level 1 (direct observations / strong correlations) . Level 2 (indirect observations / moderate correlations) . Level 3 (theoretical / potential correlations) - Within each level, discuss what the key points / observations / guidelines are and how they correlate (or don't correlate) across projects. - Summarize key points / thoughts in a concluding paragraph.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** Both of these sections have been revised considerably in light of these and other reviewers' comments, with the conceptual framework revision consolidated in Chapter 2 and the design considerations in Chapter 5 presented by zone.

	Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482278	Hydraulics	Other	n/a	n/a	n/a

(Page 5-1, Section 5.1.2, Table 1) At this point in time regarding SFO development, the discussion of basic assumptions / conceptual framework as presented in "SFO Premises" or "Revised Premises" may be more confusing / too simplistic than helpful. For example, the Conveyance Zone and Outfall Zone premise of "it's safe" really doesn't add much value to what is being communicated. Another example in the Discovery Zone regarding fish discover flow nets because "the SFO flow net has minimal competition from flow nets associated with other passage routes" is based on logic / observations. However, again it seems it might be too simplistic given what we know / don't know now (per discussions in Table 2-1 and in other places). Consider eliminating the "premise" format of ideas, etc. and carry key thoughts from this section into an expanded summary section / table (per previous Comment 1482277).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

Revised 04-May-07.

1-0	Evaluation **Concurred** As noted in response to #1482277, this section has been reorganized and re-written. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482279	Hydraulics	Other	n/a	n/a	n/a

(Page 5-2 and 5-3, Decision Discussion). I like the logic path that is being used to try to come up with ways to possibly optimize performance in the Decision Zone. I believe, though, the discussion regarding entrance velocity and distance from the center-point to the entrance of any wall may be too simplistic / may be missing some key points. It seems like the rate of acceleration (and other factors?) may still play a critical role. I would suggest more discussions on this (plus contacting Goodwin to get his perspective.)

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** We have re-written this section taking this and other reviewer's comments into account. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482280	Hydraulics	Other	n/a	n/a	n/a

(Page 5-3, Conveyance and Outfall paragraphs) I would suggest adding a statement saying something to the effect, "Studies are ongoing at different projects to determine if there are any long-term SFO survival effects (beyond what we can measure with direct methods) that might be associated with the different type of conveyance and outfall structures".

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0	Evaluation **Concurred** This statement was added. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1482281	Hydraulics	Other	n/a	n/a	n/a

(Page 5-3, bulleted guideline paragraphs) There are very good points that are listed in this section, but I do have several comments / clarification thoughts regarding some of the thoughts listed in these bullets. For example, [first bullet] what will the term "mass flow" mean to the common reader, [second bullet] how confident are we that SFO placements at Z-dams would most always be best within the cul-de-sac, [sixth bullet] would we be concerned about less than optimal performance if we had rapid acceleration occurring directly upstream of the entrance but occurring outside a confined SFO, others ...) Since this is such an important section, it might be worth having one more "limited" conference call discussion with key team members / reviewers of the report on just this one section prior to final completion of the report.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0 Evaluation **Concurred**
The term "mass flow" was changed to "all the flow"; the wording was revised to clarify the cul-de-sac statement; and the statement concerning flow acceleration has been expanded.

Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07

Backcheck not conducted

Current Comment Status: **Comment Open**

1482283	Hydraulics	Other	n/a	n/a	n/a

(Page 5-4, Section 5.2, paragraph 6) Suggest modifying the sentence, "Develop a CFD model of the project .....patterns)., to "Develop a CFD and / or physical model of the project ....patterns).

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0 Evaluation **Concurred**
The statement was modified as suggested.

Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07

Backcheck not conducted

Current Comment Status: **Comment Open**

1482284	Hydraulics	Other	n/a	n/a	n/a

(Page 5-5, Section 5.3, Information Deficiencies). "Information deficiencies" might be better termed "Potential Areas for Additional Research". This section could probably be significantly modified / expanded to include more topics such as what is the point of diminishing returns (for different sized projects) with respect to "bigger SFO entrances / more flow the better", what different type of SFO types / designs might be more effective for different species, what rate of acceleration / criteria leading up to and passing into different types of SFO structures would be optimal, etc. At this stage of the report, it might be best to just list potential research needs in simple / limited bullet fashion without much explanation at this point.

Submitted By: Lynn Reese (509-527-7531). Submitted On: 04-May-07

1-0 Evaluation **Concurred**
We have renamed the section and addressed these and other research topics.

Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07

Backcheck not conducted

Current Comment Status: **Comment Open**

1488190	Environmental Engineering	Technical Report	n/a	n/a	n/a

General comment. No explanation/hypothesis is given for why fish eventually pass SFO and other outlets that don't meet criterion. This is a critical process not yet discussed/addressed for which a hypothesis already exists – the SVP hypothesis already quoted in the report. Consider this: without acclimatization (i.e., if neither the fish nor threshold changed from the fish's perspective) fish that encounter unacceptable hydraulic or physical thresholds at the project would never pass the dam. Of course, fish are observed to pass (eventually) through outlets they initially reject suggesting some form of acclimatization occurs and should be considered. If this process was driven largely by changing hydraulics, steady-state CFD modeling would have limited value. As it is, the SVP hypothesis provides an explanation for why fish eventually pass through outlets they initially reject, even with steady-state hydraulics (see Goodwin et al. 2006a; 2006b for more information). Briefly, the explanation is as follows: fish respond to hydraulics and other physical conditions based on the difference between (1) the stimulus intensity at the fish's location and (2) the ambient condition/intensity to which the fish is already acclimatized. The measure of whether a fish responds to the stimulus is based (simply speaking) on whether the difference between (1) and (2) exceeds a threshold level. As the fish acclimatizes to the intensity of a stimulus, the difference between (1) and (2) decreases and eventually the fish will not perceive or respond to the threshold (e.g., before capture velocity), and exit the forebay. This is one of the major findings of the Numerical Fish Surrogate research and, we believe, explains why fish eventually pass through high-energy exit routes they may initially reject. Acclimatization also means that two or more fish may not respond in an identical way to the same stimulus at the same location/time because usually fish will have different levels of acclimatization (2). The attribute of different behaviors at the same location/time is observed regularly at projects and, we believe, further supports the notion of acclimatization as an important process. It should be noted that this approach is consistent with the Weber-Fechner Law – a biological law you can read more about, if you wish, at: http://en.wikipedia.org/wiki/Weber-Fechner_Law

Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07

1-0	Evaluation **Concurred** Based on Goodwin's collective comments, 1488190-1488193 regarding our interpretation and application of the elements from the Numerical Fish Surrogate model, we have revised all sections of the report addressing this topic. We have abandoned reliance on the SVP hypothesis to support the criteria we used in the report, and have revised the text accordingly, both in chapters 4 and 5. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1488191	Environmental Engineering	Technical Report	section 4.4.2 "Rating SFO Performance"	pg 4-8	n/a

"Strain" needs to be introduced/described in this section as it relates to the SVP hypothesis. I suggest the following: In the context of the strain-velocity-pressure (SVP) hypothesis "strain" is short for "total hydraulic strain", a metric Goodwin et al. (2006a; 2006b) use to quantify flow field distortion in steady flow. They calculate strain by summing the absolute values of all 9 spatial velocity gradients.

Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07

1-0	Evaluation **Concurred** See response to 1488190. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1488192	Environmental Engineering	Technical Report	section 4.4.2 "Rating SFO Performance" & section 5.1.3 "SFO Zones: Decision"	pg 4-8 & pg 5-2	n/a

The SVP hypothesis does not support parameter (2) "the minimum distance from the center-point of the entrance, to any wall" as the SVP hypothesis is dependent on total hydraulic strain, no matter how it is generated. Relatively, boundaries do have an elevated effect on total hydraulic strain, but the contribution to total hydraulic strain is probably trumped by the flow rate contribution, especially when comparing/contrasting low (summer) and high (spring) flows. The following is a hypothesis that should be evaluated through analysis, but for now I think it will suffice to illustrate that the metric of "the minimum distance from the center-point of the entrance, to any wall" is overly simplistic. The hypothesis is that at relatively small flows the boundary may be a dominant factor in eliciting total hydraulic strain in/around the SFO but as the flow increases (and especially at high flows) the contribution of SFO boundaries to total hydraulic strain is minimal. Consider this: at a moderate flow rate into a SFO total hydraulic strain near the boundary may be, say, 0.8 sec-1 while in the middle of the SFO (farthest point away from the boundaries) it is, say, 0.4 sec-1. As the flow rate increases substantially several things may happen: (a) total hydraulic strain in the middle of the SFO may exceed, say, 0.9 sec-1, (b) total hydraulic strain due to the boundary may propagate further into the SFO entrance negating any benefit of it being larger, and (c) the increasing velocity gradient in-line with the flow vector entering the SFO may cause total hydraulic strain to propagate further into the forebay. See "07ERDC_SurfaceBypassReportComments.ppt" – just FYI. Notice I only had one flow rate each for the SBC/RSW to work with.

(Attachment: 07ERDC_SurfaceBypassReportComments.ppt)

Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07

1-0	Evaluation **Concurred** See response to 1488190. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1488193	Environmental Engineering	Technical Report	section 4.4.2 "Rating SFO Performance" & section 5.1.3 "SFO Zones: Decision"	pg 4-8 & pg 5-2	n/a

The following were good, appropriate take-away messages from the SVP hypothesis with recommended modifications in brackets: pg 4-8, section 4.4.2 "Rating SFO Performance" "If trapping velocity can be achieved prior to the smolts sensing the [elevated] strain field, entrance efficiency will be maximized." pg 5-2, section 5.1.3 "SFO Zones: Decision" "...if trapping velocity can be achieved prior to the smolts sensing the [elevated] strain field, entrance efficiency will likely be high." I just think there's too much, unsubstantiated focus on the SFO opening size contributing to the total hydraulic strain field.

Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07

1-0	Evaluation **Concurred** See response to 1488190. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1488194	Environmental Engineering	Technical Report	Figure 4-2 "Hydraulic Approach Profiles of SFO Project Sites"	n/a	n/a

Replace plot of Lower Granite SBC (CFD data) SFO near-field hydraulic conditions with new (updated) data. See "07ERDC_Surface Bypass Report Comments_FixToFigure4-2.ppt" – raw data available in "07ERDC_Streamtrace-Data-For-LGR-SH4-and-A2.xls".

(Attachment: 07ERDC_SurfaceBypassReportComments_FixToFigure4-2.ppt)

Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07

1-0	Evaluation **Concurred** The figures are being replaced with the new data. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07

	Backcheck not conducted
	Current Comment Status: **Comment Open**

1488195	Environmental Engineering	Technical Report	Figure 4-2 "Hydraulic Approach Profiles of SFO Project Sites"	n/a	n/a

If you wish, replace plot of Lower Granite RSW with CFD modeled data (in lieu of physical modeled data) of the SFO near-field hydraulic conditions. See "07ERDC_Surface Bypass Report Comments_FixToFigure4-2.ppt" – raw data available in "07ERDC_Streamtrace-Data-For-LGR-SH4-and-A2.xls".

(Attachment: 07ERDC_Streamtrace-Data-For-LGR-SH4-and-A2.xls)

Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07

1-0	Evaluation **Concurred** Thank you! We will look at these data and determine which set to use. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1488196	Environmental Engineering	Technical Report	section 5.2 "Development Process Model"	pg 5-4	n/a

Suggest a modification along the lines of the following: 7. Develop physical and/or CFD models of SFO alternatives and use these models to investigate the effects of geometric arrangements and flows on flow conditions in the decision zone as compared to best of class hydraulic criteria. Investigation is best pursued through a combination of expert judgment, statistical analyses, and, when appropriate, behavioral modeling such as through the Numerical Fish Surrogate to implement the SVP or other prevailing behavioral hypothesis. or 7. Develop physical, CFD, and/or NFS models of SFO alternatives and use these models to investigate the effects of geometric arrangements and flows on flow conditions in the decision zone as compared to best of class hydraulic criteria. Explanation: The SVP hypothesis is used as the basis to describe SFO entrance decisions earlier in the report, but step 7 presently suggests physical/CFD modeling are sufficient. Given the SVP hypothesis was developed through the Numerical Fish Surrogate and is required for full implementation of its critical aspects, such as acclimatization, it seems appropriate to balance suggested use of physical/CFD modeling (and monitoring analyses) with that of the Numerical Fish Surrogate. This is particularly relevant given that, in addition to describing the "Decision" phase, the SVP hypothesis also already numerically describes/implements the "Approach" and "Discovery" phases (Goodwin et al., 2006a; 2006b) as evidenced by its application (via the Numerical Fish Surrogate) in accurately capturing patterns of fish movement at/near the LGR trash boom and Behavioral Guidance Structure away from the dam superstructure. Just as you wouldn't use/model hydraulics using statistics (instead of CFD), statistics are unable to implement many of the components of the SVP hypothesis as they are through the Numerical Fish Surrogate.

Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07

1-0	Evaluation **Concurred** The first alternative modification will be incorporated in the report as it best fits with the current re-write of the SFO rating criteria without reliance on the SVP hypothesis. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1488197	Environmental Engineering	Technical Report	section 5.3 "Information Deficiencies"	pg 5-5	n/a

I question the following in the first subsection on: The relationship between hydraulic and other physical conditions and fish responses within about 10 m of SFOs is uncertain. Comment #1: The comment that "average" flow conditions are a problem issue warranting in-situ field monitoring of hydraulic patterns is misplaced. Why? Methods need to be

developed that allow the Corps to better forecast the outcomes of management actions. Existing and near-future modeling (CFD) technology will allow the Corps to forecast, at best, "average" flow conditions. While understanding the relationships between fish and "real" (unmodeled) hydraulics is a wonderful endeavor as part of a broader 'basic research' effort, it would not be of much management value as presently (and through the near-future) it will be impossible to forecast those "real" hydraulics with any degree of accuracy. Since only "average" hydraulic conditions (due to future management actions) are accessible to CFD model forecasting, that is where the focus should be. There is a tremendous amount of work that could/should go into better synchronizing already archived as well as future empirical (fish) data and "averaged" hydraulic conditions – I think analyzing these, better synchronized data sets is where the effort should be placed. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** This section has been re-written in recognition of the comment. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1488198	Environmental Engineering	Technical Report	section 5.3	pg 5-5	n/a
I question the following in the first subsection on: The relationship between hydraulic and other physical conditions and fish responses within about 10 m of SFOs is uncertain. Comment #2: If there is to be work on understanding the relationships between fish and "real" (unmodeled) hydraulics as part of a broader 'basic research' effort, this needs to be approached in a lab setting where stimulus conditions can be rigorously controlled and other, non-hydraulic stimuli (e.g., boat wakes, conspecifics, predators, shadows, etc.) can be appropriately discounted. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** This section has been re-written in recognition of the comment. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1488199	Environmental Engineering	Technical Report	section 5.3	pg 5-5	n/a
I question the following in the first subsection on: The relationship between hydraulic and other physical conditions and fish responses within about 10 m of SFOs is uncertain. Comment #3: Field instrumentation provides, at best, limited 3-D coverage of hydraulic conditions, so synchronizing empirical field (fish) data with 2-D (or partial/pseudo 3-D) hydraulic patterns seems as if it'd have very limited value. CFD modeling has matured to a point where a variety of means (e.g., time-varying RANS or LES simulations) can be used to transform measurements of field hydraulics into a far more valuable form of comprehensive 3-D hydraulic information. This more comprehensive 3-D hydraulic information would be more valuable for evaluating the relationships between synchronized 3-D field (fish) data and hydraulic patterns. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** This section has been re-written in recognition of the comment. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1488200	Environmental Engineering	Technical Report	section 5.3	pg 5-5	n/a

I question the following in the first subsection on: The relationship between hydraulic and other physical conditions and fish responses within about 10 m of SFOs is uncertain. Comment #4: To date it seems statistical analyses of field monitoring data to understand/develop a detailed, quantitative, and portable description of fish behavior response to hydraulic patterns have proved inadequate. Why is the recommendation of more statistical analyses not more of the same? Is it more detailed data or a new/additional approach to analysis (other than just statistics) that is needed? Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** This section has been re-written in recognition of the comment. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1488201	Environmental Engineering	Technical Report	section 5.3	pg 5-5	n/a
I question the following in the first subsection on: The relationship between hydraulic and other physical conditions and fish responses within about 10 m of SFOs is uncertain. Comment #5: The concept of a threshold in the Decision Zone at an SFO has been studied for quite some time with little result. One reason may be that, presently, the concept of 'threshold' in (b) does not account for one of the fundamental laws in biology – the Weber-Fechner Law – which states that to detect a change in a stimulus intensity it must exceed the background intensity by a threshold "just noticeable difference". I expanded on this in my first comment. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** This section has been re-written in recognition of the comment. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1488202	Environmental Engineering	Technical Report	section 5.3 "Information Deficiencies"	pg 5-5	n/a
Suggest appending the following as an item in the first subsection: The relationship between hydraulic and other physical conditions and fish responses within about 10 m of SFOs is uncertain. #) further evaluate facets of the SVP hypothesis and dynamics such as acclimatization through Numerical Fish Surrogate research/evaluation with additional empirical and CFD modeled data. Explanation: Statistical methods are a form of analysis technique not germane in every context. Just as you wouldn't use/model hydraulics using statistics (instead of CFD), statistics are unable to implement many of the components of the SVP hypothesis as they are through the Numerical Fish Surrogate. Further evaluation of the SVP hypothesis would require use of the Numerical Fish Surrogate; it could be used to evaluate the SVP hypothesis through better synchronized flow and fish movement/passage data at additional projects where the raw data already exists. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** This section has been re-written in recognition of the comment. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1488203	Environmental	Technical Report	section 5.3 "Information	pg 5-5	n/a

	Engineering		Deficiencies"		

Suggest appending the following as an item in the second subsection: The need for gradual shaping (i.e., acceleration criteria) at an SFO entrance is not well established. Research is needed as to whether flow rates can override the relative contribution of SFO boundaries to total hydraulic strain and, if so, what are the thresholds and what are they dependent on.

Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07

1-0	Evaluation **Concurred** The suggested text has been appended. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1488204	Environmental Engineering	Technical Report	section 5.4 "Next Steps"	pg 5-6	n/a

Suggest the following modification to the 3rd bulleted item on the page: introduce some of the key facets of the SVP hypothesis and its application in modeling fish behavior through the Numerical Fish Surrogate. Explanation #1: as it is, the report only introduces some of the key facets of the SVP hypothesis; the role of acclimatization, for instance, is a key facet of the SVP hypothesis and Numerical Fish Surrogate not presently discussed in the report. Goodwin et al. (2006a; 2006b) can be cited for more information. Explanation #2: a take-away message should be that the Numerical Fish Surrogate (specifically, the Eulerian-Lagrangian-agent method) provided the tool necessary to develop the SVP hypothesis, not the other way around.

Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07

1-0	Evaluation **Concurred** We will be adding some language recommending incorporation of the NFS and SVP hypothesis in a future update of the compendium. This detailed analysis was beyond the scope of the present document. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1488205	Environmental Engineering	Technical Report	"Table 3. Workshop Attendees"	pg A-10	n/a

Change "Affiliation" as: Andy Goodwin to "USACE ERDC"

Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07

1-0	Evaluation **Concurred** Change has been made. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1488206	Environmental Engineering	Technical Report	n/a	n/a	n/a

No reference is given in the Bibliography (Appendix D) for Goodwin et al. (2006). There are two germane "Goodwin et al. (2006)" publications for this report; I suggest changing the existing citation for "Goodwin et al. (2006)" presently used in the body text of the report to "Goodwin et al. (2006a)" with the reference as: Goodwin, R. A., Nestler, J. M., Anderson, J. J., Smith, D. L., Tillman, D., Toney, T., Weber, L. J., Li, S., Cheng, J.-R., and Hunter, R. M., 2006a. "The

Numerical Fish Surrogate: Converting Observed Patterns in Fish Movement and Passage to a Mechanistic Hypothesis of Behavior for Engineering Design Support", Draft Final Technical Report ERDC/EL-06, U.S. Army Engineer Research and Development Center, Vicksburg, MS. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** Reference has been added. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1488208	Environmental Engineering	Technical Report	section D.1.4.2 "Wanapum: Biological Evaluation"	pg D-14	n/a
There are a number of published works not yet cited in the report (i.e., work on decoding/understanding the relationship between hydraulics and fish movement/passage in the Columbia River basin) that are germane to this report: Please add the following: 5. Weber, L. J., Goodwin, R. A., Li, S., Nestler, J. M., and Anderson, J. J. (2006). "Application of an Eulerian–Lagrangian–Agent method (ELAM) to rank alternative designs of a juvenile fish passage facility." Journal of Hydroinformatics, 8(4), 271–295. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** Reference has been added. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1488209	Environmental Engineering	Technical Report	section D.5.2 "General: Biological Evaluation"	pg D-44	n/a
There are a number of published works not yet cited in the report (i.e., work on decoding/understanding the relationship between hydraulics and fish movement/passage in the Columbia River basin) that are germane to this report: Please add the following: 12. Goodwin, R. A., Nestler, J. M., Anderson, J. J., Weber, L. J., and Loucks, D. P. (2006b). "Forecasting 3-D fish movement behavior using a Eulerian-Lagrangian-agent method (ELAM)." Ecological Modelling, 192, 197-223. 13. Goodwin, R. A., Nestler, J. M., Anderson, J. J., and Cheng, J.-R. (2007). "Understanding hydrodynamics from the fish's point of view, Part I: Integrating CFD modeling, individual movement, and spatial/cognitive ecology." Proceedings of the 6th International Symposium on Ecohydraulics, 18 - 23 February 2007, Christchurch, New Zealand. 14. Nestler, J. M., Goodwin, R. A., Anderson, J. J., and Smith, D. L. (2007). "Understanding hydrodynamics from the fish's point of view, Part II: Integrating flow field distortion, sensory biology, and geomorphology." Proceedings of the 6th International Symposium on Ecohydraulics, 18 - 23 February 2007, Christchurch, New Zealand. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** References have been added. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				

1488210	Environmental Engineering	Technical Report	section D.2.1.3 "Lower Granite: Numerical Modeling"	pg D-22	n/a
There are a number of published works not yet cited in the report (i.e., work on decoding/understanding the relationship between hydraulics and fish movement/passage in the Columbia River basin) that are germane to this report: Please add the following: 2. Goodwin, R. A., Nestler, J. M., Anderson, J. J., and Weber, L. J. (2004). "Virtual fish to evaluate bypass structures for endangered species." Proceedings of the 5th International Symposium on Ecohydraulics, 12 – 17 September 2004, Madrid, Spain. 3. Goodwin, R. A., Nestler, J. M., Anderson, J. J., and Weber, L. J. (2004). "Forecast simulations of 3-D fish response to hydraulic structures." Proceedings of the World Water & Environmental Resources Congress, American Society of Civil Engineers, 27 June – 1 July 2004, Salt Lake City, Utah. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** References have been added. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1488211	Environmental Engineering	Technical Report	section D.5.2 "General: Biological Evaluation"	pg D-44	n/a
Please correct the following reference as: 12. Goodwin, R. A., Anderson, J. J., and Nestler, J. M. (2004). "Decoding 3-D movement patterns of fish in response to hydrodynamics and water quality for forecast simulation." Proceedings of the 6th International Conference on Hydroinformatics 2004, Liong, Phoon, and Babovic, eds., World Scientific Publishing Company, 21 – 24 June 2004, Singapore. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** Correction has been made Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				
1488213	Environmental Engineering	Technical Report	section D.5.3 "General: Multidisciplinary"	pg D-45	n/a
Please correct the following reference as: 2. Goodwin, R. A., Nestler, J. M., Weber, L., Lai, Y. G., and Loucks, D. P. (2001). "Ecologically sensitive hydraulic design for rivers: lessons learned in coupled modeling for improved fish passage." Proceedings of the ASCE Specialty Conference on Wetlands Engineering and River Restoration 2001, 25 - 31 August 2001, Reno, Nevada. Submitted By: Andy Goodwin ((503) 808-4872). Submitted On: 10-May-07					
1-0	Evaluation **Concurred** Correction has been made Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07				
	Backcheck not conducted				
	Current Comment Status: **Comment Open**				

1489265	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: Page 4-2, top para.)

Bonneville has one active SFO, the B2CC. The B1 PSC no longer exists. It was dismantled several years ago.

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 11-May-07

1-0	Evaluation **Non-concurred** The B1 ice and trash sluice is still operated. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489271	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: Page 4-9, 2nd para.)

Suggest removing Consumer Reports when describing the rating table. I think saying a rating table was constructed will do.

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 11-May-07

1-0	Evaluation **Concurred** The entire section has been re-written and this table is no longer used. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489274	Design Team Leader	Technical Report	n/a	n/a	n/a

(Document Reference: Page 4-9,)

Suggest defining the rating score somewhere before the table. For example 1 being Poor and 5 being Best.

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 11-May-07

1-0	Evaluation **Concurred** This table and numerical rating has been removed as a result of response to comments from other reviewers. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489444	Hydraulics	Technical Report	General	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

An executive summary appears to be more appropriate for this this document as opposed to an abstract. I suggest a comprehensive executive summary so that the readers get a fairly good idea about the objectives and the outcome of this effort without going through the entire document.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Concurred** A comprehensive Executive Summary is being prepared for the 100 % submittal. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489449	Hydraulics	Technical Report	Section 2.2	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

The detailed definition of critical flow presented in section 2.2 including mention of wave celerity- does not appear to be necessary for the purpose of this document. Many readers may get confuse by the terminology used in this section. I think we can simply write the equation for Froude Number in terms of flow velocity, flow depth and acceleration due to gravity, and define sub, super, and critical flow.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Non-concurred** This classic definition of flow regimes will have more relevance to the lay or non-engineering reader than a number. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489457	Hydraulics	Technical Report	Section 3.0 Synopses of SFO Development	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

It will be good to have a table with a summary of all the projects described in Section 3.2. I am thinking about a Table like the one in Appendix B- may be redress it a bit and we do not need all the information as in Appendix B either. Moreover, Appendix B has been referred many times in Chapter 4. It will be helpful for the readers who do not want to go through all the descriptions and want see a snapshot of all the projects and relevant parameters in a chart.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Concurred** As a compromise, we have included a reference to the Matrix in Appendix B is the introductory section of Chapter 3. We feel it would be redundant to provide another very large table with repetitive information that is presented elsewhere and would not be able to decide what would be the essential relevant data to include in the table. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489463	Hydraulics	Technical Report	Section 3.0 Synopses of SFO Development	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)

Coordinating Discipline(s): Hydraulics

All the aerial photos should be larger. These photos are too small now. May be expand up to the full width of the page and the height will be adjusted auomatically. Figure 3-31 Aerial photo of Upper Baker Project- should be 'Future FSC' .

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Concurred** The photos have all been re-sized. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489464	Hydraulics	Technical Report	Table 3-1	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

Suggest presenting the results up to two decimal points.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Concurred** The table has been revised. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489466	Hydraulics	Technical Report	Section 3.2.1 Page 3-5	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

The last bullet 'The SFO at Wells...' seems redundant.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Non-concurred** This bullet provides a summary statement of the information in the previous bullets. If any thing, it should be a stand-alone sentence instead of a bullet. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489475	Hydraulics	Technical Report	Section 2-3 Page 2-2	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

'Bioengineers' - do we mean Biologists and Engineers, or Biologists with engineering knowledge, or engineers who like to delve into biology.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **For Information Only** Bioengineers refers to the group, both biologists and engineers, who work on the integrated design of fisheries structures. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489478	Hydraulics	Technical Report	Section 3.0	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

Suggest doing a global search of 'physically modeled' and replacing this term with physical model or by using a physical model. Some cases it may require rewriting the sentences.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Concurred** It will be changed where appropriate. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489483	Hydraulics	Technical Report	Section 3.0	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

The term 'Developers' has been used in many places. The 'design team' sounds more appropriate or planning and design team.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Concurred** Changes will be made where appropriate. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489490	Hydraulics	Technical Report	Section 4.2.2 - Page 4-4 - 3rd para from the top	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

'Prior to this synthesis ....this not to be the case' - I am not sure if I look at it the same way. I do not think we have enough data point for the summer Bio-index to make such a statement. The Spring index has 15 data point where as the Summer index has only 8 data points.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Concurred** This statement is being reviewed in light of possible additional summer indices. However, we must draw some conclusion from data available, even if the data sets are not of the same size. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489505	Hydraulics	Technical Report	Section 4.4.2 Page 4-8	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

In general I agree with the rating approach and procedure. I think the authors have done a great job in synthesizing the available SFO performance information to find a common thread and measure the performance with a common stick. It will be good to provide a bit more introduction/information of Andy's SVP index. It could be done within the scope of this section. It wil be difficult for folks to follow this section if they are not already familiar with Andy's work. One general comment regarding the SVP index- strain could be a mid-flow phenomena depending on the flow situation, not only from the structural boundaries. I agree with the impact of strain signature on fish migration- but we can define it as - proximity to boundary layer of structural members as well.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Concurred** This section of the report has been re-written in light of the comments of several reviewers to eliminate dependence on the SVP hypothesis. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489513	Hydraulics	Technical Report	Section 5-4 Next Steps	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

how about having the workshop and compendium update in every 3 to 4 years instead of every 2 years. Two years seem to be a short time for signficant changes in the SFO world that would warrant a workshop of update of technology.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07

1-0	Evaluation **Concurred** The interval has been increased to 3 to 4 years. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

1489515	Hydraulics	Technical Report	General	n/a	n/a

(Document Reference: Surface Bypass Comprehensive Report)
Coordinating Discipline(s): Hydraulics

I have some editorial comments throughout the document which I will provide to ENSR PM for this project for his considerations.

Submitted By: Mizan Rashid (425-881-7700). Submitted On: 11-May-07	
1-0	Evaluation **Concurred** Thank you. Submitted By: Charles Sweeney (425-881-7700) Submitted On: 27-Jun-07
	Backcheck not conducted
	Current Comment Status: **Comment Open**

Thoughts on Surface Bypass Program Comprehensive Review Report
90% document

By – Laurie Ebner
May 20th 2007

Talked to Chick on Friday May 18th.

I think the report is well done and I think if hydraulic engineers and biologist will take the time and read through Sections 4 and 5 and interpret for a site specific project (together) specific surface bypass criteria can be established.

Of course I have some comments.

- In the report in section 1.2 it explains that the "we" is the authors but since there isn't a list of authors and it is a COE report I think some additional explanation is warranted. I think that it could be done here in this section or as a disclaimer in the front of the report. Chick did explain that there will be an author list when the final report is written. But I still think it would be good to put up front that:

  The conclusions and recommendations presented in this report are those of the authors and are not necessarily the conclusions and recommendations of ENSR, the COE or the PUDs.

  In addition I would like to see something like this put in the report: PUDs graciously provided or allowed their contractors to provide information on their surface bypass projects to be included in this report.

  <u>Comment accepted. The suggested changes have been made.</u>

- In Section 4, page 3-3, section 4.2.1, step 2. Do the authors know that regional players evaluated the multiple years of data and summarized if for the COE projects and agreed to biological numbers to be used for spring (Chinook and steelhead). I wouldn't change what the authors did but the fact that they may be different may need to be stated.

<u>Comment not accepted. It is beyond the scope of the existing task order, especially at this late date, to compare our data summary with a summary prepared by others that we have not even been provided.</u>

- Page 4-14 the first bullet at the top of the page. I think what the conclusion is distribution of Chinook at a project is not season specific. The biological data does show a definite difference in project survival for subs and that could be a function of: size of migrating fish, total volume of river, water temperature and activity level of predators.

Comment accepted. This section of the report has been re-written in response to this and other reviewers comments.

- Page 5-2 paragraph called Approach. I am not sure that TDA is the best example and my reasoning is because we assume more subs go through turbines in the summer at the same spill percentage which is inconsistent with the conclusion stated on page 4-14. I would most likely use Bonneville as an example – where we split fish between the three channels based on flow with a slight modification due to spill volume.

Comment accepted. This section of the report has been re-written in response to this and other reviewers comments.

- Editorial
    - Page 2-1 first paragraph in section 2.1. The last sentence needs some additional punctuation or something.

Comment accepted. This section has been revised considerably based on comments from other reviewers.

- Page 3-10 2nd paragraph: "SFO that limits of the generation of dissolved gas" – delete "of".

Comment accepted. Change was made to text.

- Page 4-5, last sentence of 4.3. I think that the location of the SFO has a significant impact on the success of the SFO and I am not sure "physical features of the SFOs" convey that message. It has been clear in the discussion. I would maybe say "physical features of the SFO at a specific project".

Comment accepted. This section has been re-written in response to this and other reviewer comments.

Comment Report: All Comments
Project: Surface Bypass Comprehensive Report
Review: 100%
Displaying 14 comments for the criteria specified in this report.

125 ms to run this page

Id	Discipline	DocType	Spec	Sheet	Detail
1707496	Hydraulics	Technical Report	n/a'	n/a	n/a
(Document Reference: iii) FCE appears on this page and is not previous explained. Submitted By: Laurie Ebner ((503) 808-4880). Submitted On: 26-Nov-07					
	Evaluation not conducted				
1707501	Hydraulics	Technical Report	n/a'	n/a	n/a
(Document Reference: v) second paragraph from the bottom delete the first involves. Submitted By: Laurie Ebner ((503) 808-4880). Submitted On: 26-Nov-07					
	Evaluation not conducted				
1707506	Hydraulics	Technical Report	n/a'	n/a	n/a
(Document Reference: Section 4) page numbers get messed up and sometimes they appear in the middle of the page and cover text. Submitted By: Laurie Ebner ((503) 808-4880). Submitted On: 26-Nov-07					
	Evaluation not conducted				
1707510	Hydraulics	Technical Report	n/a'	n/a	n/a
(Document Reference: Section 4.4) something is missing from the first paragraph. Submitted By: Laurie Ebner ((503) 808-4880). Submitted On: 26-Nov-07					
	Evaluation not conducted				
1707512	Hydraulics	Technical Report	n/a'	n/a	n/a
(Document Reference: Table 4-4) I would find this table easier to follow if the lines were included in the table. Submitted By: Laurie Ebner ((503) 808-4880). Submitted On: 26-Nov-07					
	Evaluation not conducted				

1707516	Hydraulics	Technical Report	n/a'	n/a	n/a

(Document Reference: Section 4.5 - B2 Sluice Corner Collector)

Why approximately 98%. I thought it was 100%. If this number is discounted do all other survival numbers need to be discounted.

Submitted By: Laurie Ebner ((503) 808-4880). Submitted On: 26-Nov-07

Evaluation not conducted

1707528	Hydraulics	Technical Report	n/a'	n/a	n/a

(Document Reference: 5.1)

paragraph 2 - punctuation needs to be fixed

Submitted By: Laurie Ebner ((503) 808-4880). Submitted On: 26-Nov-07

Evaluation not conducted

1707529	Hydraulics	Technical Report	n/a'	n/a	n/a

(Document Reference: Section 5)

Page numbers appearing twice on page 5-4

Submitted By: Laurie Ebner ((503) 808-4880). Submitted On: 26-Nov-07

Evaluation not conducted

1707531	Hydraulics	Technical Report	n/a'	n/a	n/a

(Document Reference: Overall)

Great report. Great resource.

Submitted By: Laurie Ebner ((503) 808-4880). Submitted On: 26-Nov-07

Evaluation not conducted

1709122	Design Team Leader	Other	n/a'	n/a	n/a

(Document Reference: Sec. 5-3 2nd para. 5th sent.)

suggest "...Corps and others..."

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 27-Nov-07

Evaluation not conducted

1709125	Design Team Leader	Other	n/a'	n/a	n/a

(Document Reference: Sec. 5-3 4th para. 4th ent.)

The sentence is not clear.

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 27-Nov-07

	Evaluation not conducted

1709126	Design Team Leader	Other	n/a'	n/a	n/a

(Document Reference: Sec. 5-4 1st para, 1st sent.)

Suggest removing "called"

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 27-Nov-07

	Evaluation not conducted

1709132	Design Team Leader	Other	n/a'	n/a	n/a

(Document Reference: Page 5-5)

Section 5-4 as shown should be corrected to Section 5.5(?).

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 27-Nov-07

	Evaluation not conducted

1709141	Design Team Leader	Other	n/a'	n/a	n/a

(Document Reference: Page 5-5, last bullet)

Suggest rewriting to be a bit more formal.

Submitted By: Randy Lee ((503) 808-4876). Submitted On: 27-Nov-07

	Evaluation not conducted